Quality Pricing-to-Market*

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Abstract

We examine firm's pricing-to-market decisions in vertically differentiated industries featuring a large number of firms that compete monopolistically in the quality space. Firms sell goods of heterogeneous quality to consumers with non-homothetic preferences that differ in their income and thus their marginal willingness to pay for quality increments. We derive closed-form solutions for the pricing game under costly international trade, thus establishing existence and uniqueness. We then examine how the interaction of good quality and market demand for quality affects firms' pricing-to-market decisions. The relative price of high quality goods compared to that of low quality goods is an increasing function of the income in the destination market. When relative costs change, the rate of exchange rate pass-through is decreasing in quality in high income countries, yet increasing in quality in low-income countries. We then document that these predictions receive empirical support in a dataset of prices and quality in the European car industry.

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1 Introduction

Empirical evidence suggests that vertical product differentiation is a key determinant of international trade patterns. Richer nations tend to both export (Schott (2004); Hummels and Klenow (2005)) and import (Hummels and Skiba (2004); Hallak (2006)) goods with higher unit values. Also structural estimates of product quality suggest that vertical product differentiation is of first order importance for our understanding of international trade flows.[1]

In this paper, we argue that good quality is also a key determinant of firms' pricing-to-market (PTM) decisions and that modeling how quality is priced to market hence has implications for one of the central puzzles in international macroeconomics: relative prices of identical goods vary widely across different markets and co-move closely with the exchange rate even when they are measured at the border and thus do not include a retail distribution component (see e.g. Obstfeld and Rogoff (2000) or Atkeson and Burstein (2008)).

The focus of our analysis is to theoretically model how goods of different quality are priced differently depending on the income distribution of the destination market. We develop a model that draws on recent theories featuring non-homothetic preferences with fixed markups (see e.g. Fajgelbaum et al. (2011)); we derive variable markups by drawing on the literature on quality competition in the field of industrial organization (see Mussa and Rosen (1978), Gabszewicz and Thisse (1979 and 1980), and Shaked and Sutton (1982 and 1983)).

The main contribution of our paper is to solve for the unique price equilibrium in a multi-firm model of international trade with spatial competition in quality and to examine how the interaction of good characteristics and market demand for such characteristics affects firm's pricing-to-market decisions in vertically differentiated markets. In our framework, the industry is populated by a large number of firms, each producing a good of unique quality. These firms are selling to consumers with non-homothetic preferences that differ in their income and thus their marginal willingness to pay for quality increments. Strictly positive markups arise since each firm holds a blueprint of a certain quality, giving it market power over a subset of consumers. The degree of this market power is endogenous, depending on the prices and qualities of adjacent competitors, on the density of quality competition, and on the distribution of consumers' valuations for quality.

International trade, by increasing the density of firms in the quality spectrum, intensifies competition and thus puts downward pressure on prices. This effect operates even if the volume

[1] See Khandewal (2010) and Hallak and Schott (2011); as well as Manova and Zhang (2012).

of trade is low: the "toughening" of spatial competition in the quality dimension brought about by entry of foreign firms can have a sizeable effect on markups and prices even as trade volumes are negligibly small.[2]

We then examine how quality is priced-to-market in the equilibrium of this model. We first show that the relative price of high quality goods compared to that of low quality goods is an increasing function of income in the destination market. Our framework thus predicts that low quality goods are relatively more expensive in poor markets, while high quality goods are relatively more expensive in rich markets. Moreover, we show that, if income is high enough, then the relative export price – defined as the price charged for exported goods over the price charged in the production market – is increasing in quality.

Next, we examine the role of good quality and consumer preferences as a determinant of exchange rate pass-through. To this aim, we extend examine the response of prices to changes in the marginal cost of production. We show that the rate of exchange rate pass-through is decreasing in quality in high income countries and that it is increasing in quality in low-income countries. The reason underlying the difference in how quality affects the rate of exchange rate pass through derives from how differences in market power affect markup variability. A firm's rate of pass-through depends negatively on its market share and high quality firms command relatively larger market shares in high income countries.

We then test these predictions using a dataset of prices and product attributes in the European car industry. Specifically, we document that pricing-to-market and exchange rate pass-through are highly quality-dependent. In these markets, export prices over domestic prices are increasing in car quality and exchange rate pass-through is larger for low than for high quality cars. These relations depend on the income of the destination market: higher quality goods are relatively more expensive in markets with higher income, while exchange rate pass-through is more decreasing in quality in markets with lower income. Because we observe the price of the same car model sold on five markets, we can follow Fitzgerald and Haller (2012) and Burstein and Jaimovic (2012) and focus on the evolution of the relative price of the same good sold across different markets,

[2] We note that this preference specification is related to the models of spatial differentiation in Lancaster (1980) and Helpman (1981), who examine Hotelling's classic 'location' paradigm in open economy settings. However, as is well established in the literature of industrial organization (see e.g. Anderson et al. (1992)), such models of "spatial" competition, although widely used to reflect generic product characteristics, do not apply to competition in quality: by its very definition, quality requires that individuals agree on the ranking of varieties so that, in particular, their individually preferred "ideal variety" coincide and only the higher price tag of the universally preferred higher-quality goods causes different consumers to buy distinct qualities.

thus keeping marginal costs constant. We also account for distribution costs by using additional information on distribution cost-intensity and by utilizing the nature of distribution in the car industry.

This paper is related to three strands of literature: it is motivated by the literature on the role of quality in international trade, while it contributes to the literature on pricing-to-market (PTM) in international macroeconomics and to the literature on quality competition in industrial organization.

The first of the three literatures constitutes the basic motivation of our analysis as it provides overwhelming evidence on the importance of quality differentiation in international trade. Existing work has analyzed the role of good quality for the international product cycle (see Flam and Helpman (1987)), for the selection of goods and firms into exporting (see Hummels and Skiba (2004), Baldwin and Harrigan (2011), Johnson (2012), Kugler and Verhoogen (2012), Crozet et al. (2012), and Manova and Zhang (2012)) and for the direction of net trade flows and the volume of trade (see Linder (1961), Markusen (1986), Bergstrand (1990), Matsuyama (2000), Baier and Bergstrand (2001), Föllmi et al. (2010), Hallak (2010), Fajgelbaum et al. (2011), and Fieler (2011)). Compared to its general importance in the field of international trade, it is striking that quality has received only little attention as a determinant of PTM.[3]

The second literature our work relates to is the one on PTM, which focuses on both deviations from the law of one price (LOP) and on the degree of exchange rate pass through (ERPT).[4] Regarding price differences of identical goods across borders, Crucini et al. (2005), building on Engel (1993) and Engel and Rogers (1996), relate geographic price dispersion in Europe to characteristics of individual goods and services, whereas Simonovska (2011) empirically studies how markups are affected by national income. Deviations from the LOP have also received attention in microeconomic studies of wholesale prices (see Fitzgerald and Haller (2010) and Burstein and Jaimovic (2012)), and studies that examine both wholesale and retail prices (Gopinath et al.

[3]Further see Verhogen (2008), Choi et al. (2009), and Hallak and Sivadasan (2009). Note that Föllmi et al. (2010) derive variable markups that depend on national incomes (yet not quality) in a framework featuring non-homothetic preferences and the threat of parallel trade. Our model is closely related to the setup in Fajgelbaum et al. (2011), except that we do not assume the existence of an idiosyncratic noise term that gives rise to logistic demand; rather, we derive well-defined demand curves and variable markups directly from the non-homotheticity of preferences and the granularity of firms along the quality spectrum.

[4]The literature on the LOP and EPRT are closely interconnected. Cavallo et al. (forthcoming) focus on the evolution relative retail prices during product replacements and how such relative prices co-move with the exchange rate (see also Fitzgerald and Haller (2012)). Thereby, they also address the controversy on how product replacement biases empirical estimates of ERPT (see Nakamura and Steinsson (2012) and Gagnon et al. (2012)).

(2011) and Goldberg and Hellerstein (2011)).[5]

Regarding the LOP, our contribution is to model how market-specific preference for quality affects market-specific price differences between goods of different quality; that is, we examine how quality is priced-to-market differently depending on the market's income. By studying relative prices of high versus low quality goods, our analysis goes beyond the observation that goods are generally more expensive in markets with higher income (see Alessandria and Kaboski (2011), Simonovska (2013), Sauré (2012), and Föllmi et al. (2010)). Our results are thus related to Dvir and Strasser's (2013) finding that in the European car industry, car attributes such as air conditioning are priced-to-market depending on the country-specific demand for the respective attribute. Focusing on the attribute quality, we provide a theoretical rationale for such attribute-specific differences in relative prices and markups and we empirically document that our prediction is supported in the data.

Within the literature on PTM, our work also relates to studies examining the degree of ERPT in micro data sets and, in particular, studies examining why the rate of pass through varies widely across sectors, goods, and countries.[6] Our model extends the theoretical results of previous studies examining the relation between good quality and ERPT in the context of local distribution costs. Auer and Chaney (2009) analyze how firms pass through cost changes in a model of perfectly competitive markets featuring a market-specific distribution cost schedule that is convex in quantity due to capacity constraints, thus giving rise to variable markups and quality-dependent pass through.[7] Berman et al. (2012), building on Corsetti and Dedola (2005), develop a model in which more productive firms produce higher quality goods that are highly insensitive in local

[5]In particular the car industry has been a key focus of understanding both deviations from the LOP and the speed of convergence (see Knetter (1989), Verboven (1996), Goldberg and Verboven (2001 and 2005), Garetto (2012), and Dvir and Strasser (2013)).

[6]For import prices measured at the dock (that is, net of distribution costs), the main dimensions along which the heterogeneity of pass-through rates have recently been identified include the currency choice of invoicing as in Gopinath et al. (2010) and Goldberg and Tille (2008 and 2009); inter- versus intra-firm trade as in Neiman (2010); multi-product exporters as in Chatterjee et al. (2013); the sectoral import composition as in Goldberg and Campa (2010); market share and firm productivity (Krugman (1987), Dornbusch (1987), Feenstra et al. (1996), Yang (1997), and Berman et al. (2012), who use free on board prices) and the overall market structure of a sector affects real rigidities (see Gopinath and Itskhoki (2010a) and Auer and Schoenle (2013)); and nominal price rigidities (see Gopinath and Rigobon (2008) and Gopinath and Itskhoki (2010b)). When evaluating retail prices, also the share of the distribution costs matters for pass-through (see Bacchetta and van Wincoop (2003), Burstein et al. (2003), and Corsetti and Dedola (2005), as well as Hellerstein (2008), Nakamura and Zerom (2010), and Goldberg and Hellerstein (2013) for detailed industry studies). More generally, also the size and origin of the exchange rate movement may matter for pass-through (see, for example, Michael et al. (1997) and Burstein et al. (2005 and 2007)). Goldberg and Knetter (1997) survey an earlier literature on exchange rate pass through.

[7]Crucini and Davis (2013), although not focusing on the role of good quality, take a similar look at the role of distribution capital for pass through. The assume that capacity constraints create a convex distribution cost schedule in the short run, while long run pass through is higher since distribution capacity can adjust.

distribution costs, leading to a negative relation between quality and pass through. Recently, Chen and Juvenal (2013) and Antoniades and Zaniboni (2013) empirically document that the rate of pass through is indeed decreasing in good quality in both retail (see Antoniades and Zaniboni (2013)) and export prices (see Chen and Juvenal (2013)).[8]

In contrast to these alternative mechanisms that relate good characteristics (or more precisely the technology required to deliver them to the customer) to pass-through, the model presented in this paper relates market-specific preference for quality to market-specific price differences between goods of different quality. It thus argues that not the quality of the good itself is what is driving differences in pass through, but the interaction of quality with demand for quality. In this context, in addition to our empirical evidence presented below, in particular the results of Chen and Juvenal (2013) are noteworthy, as the authors – offering a careful empirical strategy to measure quality and examining export prices that are measured net of distribution costs – document that the negative relation between ERPT and quality is found only on high-income markets. This feature precisely corresponds to the prediction of our theory.

While vertical differentiation as a motive for trade on the one side and the determinants of PTM on the other side have received a fair amount of attention in two separate literatures, the role of vertical differentiation for firms' pricing-to-market decisions has received only limited attention. To fill this gap, we draw on a third literate, the one of quality competition in the field of industrial organization. In particular, we draw on the seminal works by Mussa and Rosen (1978), Gabszewicz and Thisse (1979 and 1980), and Shaked and Sutton (1982 and 1983). In these studies, goods of heterogeneous quality are sold to consumers with heterogeneous valuation for quality. Specifically, as this literature focuses on vertically differentiated markets in which technology is such that natural oligopolies prevail, we draw on the closed economy setup of Auer and Sauré (2013) featuring many firms. The assumption underlying the setup of Auer and Sauré is that the marginal cost of a good is convex in quality, which guarantees the existence of an equilibrium in which a countable number of firms coexist, each selling to a strict subset of the total market in a non-degenerate equilibria (see also Zweimüller and Brunner (2005) for an analysis of such an economy with marginal costs being convex in quality, thus leading to the co-existence of multiple firms).

[8]Since more productive firms tend to sell higher quality products (Baldwin and Harrigan (2011), Crozet et al. (2012), and Johnson (2012)), these empirical results are highly related to the theoretical prediction and empirical findings of Berman et al. (2012) that the degree of pass through is decreasing in firm productivity. In fact, in their appendix, Berman et al. explicitly consider this possibility. See also Chen and Juvenal (2013), as well as Antoniades (2009), Rodriguez-Lopez (2011), and Yu (2013) for related theoretical insights.

We nest the closed-economy setup of Auer and Sauré (2013) in a model of the international economy featuring trade that is subject to iceberg transportation costs. In this setup, the industry is populated by a large set of firms each producing a good of unique quality. Each firm holds a blueprint of a certain quality and has market power over a narrow set of consumers. The degree of this market power depends on the prices and qualities of adjacent competitors. If we allow for international trade, domestic firms compete with importers in the quality spectrum, and trade thus toughens the density of competition. We then derive the above-mentioned results on PTM in this model of quality competition with international trade.[9]

The remainder of the paper is organized as follows. Section 2 presents a theoretical model of quality pricing. Section 3 nests these preferences in an international economy and derives predictions for pricing-to-market. Section 4 extends the model to the case of comparative advantage and derives predictions relating quality and income to exchange rate pass through. Section 5 presents empirical evidence and Section 6 concludes.

2 The Model

In this section, we build a model of quality-pricing-to-market. On the supply side, different firms produce different qualities of the same consumption good. On the demand side, we postulate that consumers differ in their valuation for quality in the sense that, while all of them strictly prefer higher quality levels over lower ones, individuals differ in their willingness to pay for a marginal increase of quality. This type of consumer heterogeneity can lead to non-degenerate equilibria, where a countable number of firms coexist, each selling to a strict subset of the total market. We make the technological assumption of Auer and Sauré (2013) that the marginal costs of production is convex in quality (i.e. the "finitiness" condition of Shaked and Sutton (1982) is violated) so that many firms can coexist in the market. All consumers value quality but differ in their "valuation" and thus in their willingness to pay for quality, and there also exist cross-country differences in willingness to pay for quality. We begin the description of our model for an economy in autarky.

Preferences. Consumers either consume one unit of the differentiated good $\mathcal{Q}$ or none at all. A consumer with the valuation $\tilde{v}$ for quality who consumes the quality level q of the $\mathcal{Q}$-good and a

[9] To the best of our knowledge, the predictions of our model of how firms that monopolistically compete in the quality space price to market are new to the literature. Note, however, that Shaked and Sutton (1984) and Sutton (2007) have analyzed product differentiations and price setting decisions in vertically differentiated open economies characterized by the entry of a monopolist or few oligopolists. Feenstra et al. (1996) analyze how market share and oligopoly interact in the car industry, although their model is not focused on good quality.

units of good $\mathcal{A}$ derives utility $U_{\tilde{v}b}(q,a) = b\tilde{v}q + a$. Here, b is a country-specific taste-shifter, which we assume to be increasing in country-specific income for exogenous reasons such as infrastructure complementing the consumption of the $\mathcal{Q}$-good.[10] We will summarize each consumer's effective valuation v as $v = b\tilde{v}$. Normalizing the price of good $\mathcal{A}$ to unity and writing $p(q)$ for the price of quality q, we can rewrite the utility of this consumer in the following reduced form

$$U_v(q) = v \cdot q - p(q) \tag{1}$$

An important property of these preferences is that valuation and quality are complementary. The higher a consumer's valuation for quality, the more she is willing to pay for a given quality level. By focusing on the reduced form (1) we implicitly assume that the consumers with valuation v choose to purchase the $\mathcal{Q}$-type good, which is the case if and only if

$$bv \geq \min_q \{p(q)/q\} \tag{2}$$

holds. Throughout the paper, we will focus on situations where the expression on the right of (2) is zero and the condition is trivially satisfied for all positive v. Also, we assume that the individuals' expenditure is high enough to generate positive demand for good $\mathcal{A}$. In so doing, we rule out corner solutions in individual demand.

Consumers differ in their valuation v for quality q. In particular, valuation among the individuals of total mass L is uniformly distributed on the interval $[0, v_{\max}]$:

$$v \sim U([0, v_{\max}])$$

This dispersion of valuation across individuals leads to firms serving different market segments and allow them to charge monopolistic prices.

Production. Production of the $\mathcal{A}$-type good takes place at constant returns to scales with labor as the only factor. We normalize the price of the $\mathcal{A}$-good to one, which implies that wages equal unity. Production technologies of the $\mathcal{Q}$-type good exhibit increasing returns to scale and depend on the quality level produced: while the marginal cost of producing the good is constant, entry is subject to a one-time fixed cost. A firm established in the $\mathcal{Q}$-market produces at constant marginal cost of

$$c(q) = \varphi q^{\theta} \tag{3}$$

[10] Auer and Sauré (2013) document that b is an increasing function of national income in a multisector version of the utility function examined here ($U_{\tilde{v}b}(q,a)$). To abstract from the technicalities this modeling choice involves, we directly assume that b is increasing in national income.

labor units. The parameter $\varphi > 0$ governs the marginal production cost. We assume that both the fixed cost of entry as well as the marginal cost are increasing and convex in quality ($\theta > 1$).

Firms compete in prices, *i.e.* each firm sets the price for its quality to maximize its operating profits, while taking total demand and the other firms' prices as given. In the equilibrium of the entry game to which we turn later, firms need to cover their setup cost with monopoly rents. Under Bertrand competition and positive setup cost this implies that firms must be located at positive distance to each other. Hence, the number of firms is countable and we can index firms by $n \in \mathcal{N}_0 = \{0, -1, -2, ...\}$. The quality level produced by firm n is denoted by q_n. Without loss of generality we order firms by the quality level they produce so that firm 0 produces the highest quality level q_0 and all further quality levels satisfy $q_{n-1} < q_n$. Finally, we assume that the quality ratio of either pair of neighboring firms is constant

$$q_{n+1} = \delta q_n \tag{4}$$

with $\delta > 1$.[11]

Optimal Pricing in the Closed Economy. Under the preferences determined by (1), a consumer with valuation v is indifferent between two goods q_n and q_{n+1} if and only if their prices p_n and p_{n+1} are such that $v = (p_{n+1} - p_n) / (q_{n+1} - q_n)$. Thus, given $v_{\max}$ and given the prices $\{p_n\}_{n \leq 0}$, the n^{th} firm sells to all consumers with valuations v in the range $[\underline{v}_n, \ \overline{v}_n]$, where[12]

$$\underline{v}_n = \frac{p_n - p_{n-1}}{q_n - q_{n-1}} \qquad \text{and} \qquad \overline{v}_n = \begin{cases} v_{\max} & \text{if } n = 0 \\ \dfrac{p_{n+1} - p_n}{q_{n+1} - q_n} & \text{if } n < 0 \end{cases} \tag{5}$$

As a consumer with valuation $v \in (\underline{v}_n, \overline{v}_n)$ demands one unit of the variety produced by firm n, total demand of firm n equals $D_n(p_n) = [\overline{v}_n - \underline{v}_n] \, L/v_{\max}$. The optimal price p_n maximizes the operating profits, solving $\max_{p_n} (p_n - c_n) [\overline{v}_n - \underline{v}_n] \, L/v_{\max}$ so that the optimality condition is

$$[\overline{v}_n - \underline{v}_n] + (p_n - c_n) \left[\frac{d\overline{v}_n}{dp_n} - \frac{d\underline{v}_n}{dp_n} \right] = 0. \tag{6}$$

The second order condition is quickly checked to grant a maximum. Combining conditions (6)

[11] Auer and Saurè (2013) establish that a sequential entry game following the model of Schumpterian growth by Aghion and Howitt (1992) indeed leads firm to enter the industry as described in (4). See also Grossman and Helpman (1991 a,b, and c) for open economy models of Schumpeterian growth, as well as Acemoglu et al. (2006) in the context of innovation and adoption in the global economy.

[12] We will rule out undercutting, where firm n sets its quality-adjusted price to take the market share of a directly neighboring firm and compete with second-next firms.

and (5) leads to the recursive formulation of prices

$$p_n = \begin{cases} \frac{1}{2}\left[c_0 + \left(1-\delta^{-1}\right) q_0 v_{\max} + p_{-1}\right] & \text{if } n=0 \text{ and firm 0 is in Home} \\ \frac{1}{2}\left[c_n + \frac{1}{1+\delta} p_{n+1} + \frac{\delta}{\delta+1} p_{n-1}\right] & \text{if } n<0 \text{ and firm 0 is in Home} \end{cases} \tag{7}$$

which is solved by the equilibrium prices[13]

$$p_n = A_\delta \lambda_\delta^n + \alpha_\delta c_n \qquad \forall \;\; n \leq 0 \tag{8}$$

where

$$\alpha_\delta = \frac{\delta+1}{2(\delta+1) - \delta^\theta - \delta^{1-\theta}} \tag{9}$$

$$\lambda_\delta = \delta + 1 + \sqrt{\delta^2 + \delta + 1} \tag{10}$$

$$A_\delta = \frac{\lambda_\delta}{2\lambda_\delta - 1}\left(1 - \alpha_\delta\left(2-\delta^{-\theta}\right) + \frac{\delta-1}{\delta}\frac{q_0 v_{\max}}{c_0}\right) c_0 \tag{11}$$

The three components α, λ and A of the price are indexed by δ, indicating dependence of the expressions on the spacing parameter. First and foremost, however, the index δ will be used to distinguish the terms above from parallel expressions for the prices in an the open economy. δ thus indicates a *detached*, or autarkic economy.

Notice that the term α_δ from (8), which is common to firms' markups, might be positive or negative, depending on whether or not $2 < \left(\delta^\theta + \delta^{1-\theta}\right)/(\delta+1)$ holds. Nevertheless, expression (8) defines positive markups in either of the cases provided that the highest quality firm is active in the market.[14] In the following, however, we will focus on the cases with positive α_δ. This is equivalent to assuming

$$\lambda_\delta > \delta^\theta \tag{12}$$

and restricts δ to lie below an upper bound $\bar{\delta} > 1$, so that $\delta \in (1, \bar{\delta})$.[15]

For later use, we also notice that the fraction $\left(\delta^\theta + \delta^{1-\theta}\right)/(\delta+1)$ is increasing in δ, i.e.

$$\frac{d}{d\delta}\frac{\delta^\theta + \delta^{1-\theta}}{\delta+1} > 0 \tag{13}$$

[13] See Auer and Sauré (2011). Alternatively, read (8) as a special case of (16) in Proposition 2.

[14] To check this statement, write $p_n/c_n = A_\delta \left(\lambda_\delta/\delta^\theta\right)^n + \alpha_\delta$ and verify that $\alpha_\delta > 0 \Leftrightarrow \lambda_\delta/\delta^\theta < 1$. Now, consider first the case $\lambda_\delta > \delta^\theta$. If $A \geq 0$, the statement holds. If, instead $A_\delta < 0$, then $A_\delta\lambda_\delta/\delta^\theta + \alpha_\delta > 1$ implies $A_\delta \left(\lambda_\delta/\delta^\theta\right)^n + \alpha_\delta > 1$ for all $n \leq 0$. Consider next the case $\lambda_\delta < \delta^\theta$. Since $\alpha_\delta < 0$, $A_\delta > 0$ must hold if firm 0 is to have a positive markup ($A_\delta\lambda_\delta/\delta^\theta + \alpha_\delta > 1$). But this implies again that $A_\delta \left(\lambda_\delta/\delta^\theta\right)^n + \alpha_\delta > 1$ holds for all $n \leq 0$.

[15] It is quick to verify that $\lambda_\delta/\delta^\theta$ is decreasing in δ.

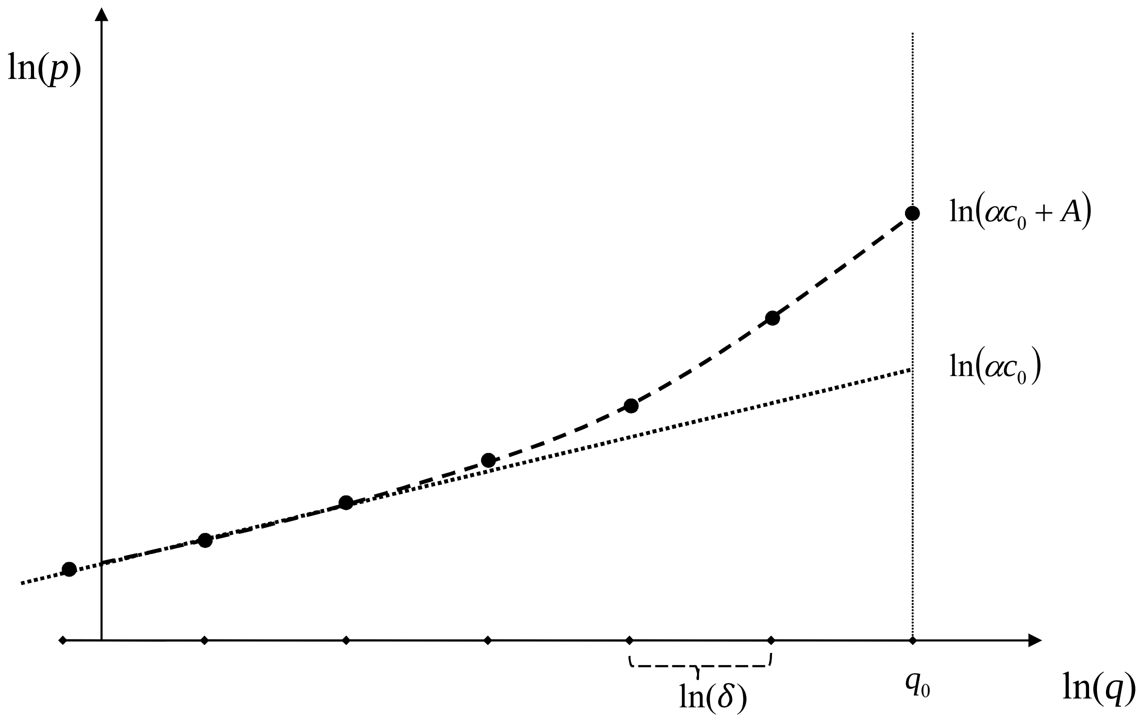

Figure 1: Equilibrium prices of quality in a closed economy. Markups consist of a constant times marginal productivity (represented by the straight line) plus a variable part that increases in quality (the difference between the bent and the straight line).

holds (see appendix).

The crucial condition for markups to be positive is thus $A_\delta + \alpha_\delta - 1 > 0$. This condition is satisfied as long as $v_{\max}$ is large enough to generate positive demand for the firm producing the highest quality (compare (8) and footnote 12). In sum, if under equal relative spacing (4) a firm with quality q sells positive quantities, then all firms with minor qualities do so. Obviously, the highest quality firm does not produce under all circumstances, *e.g.*, if the highest valuation is small so that $v_{\max}q_0 < c_0$ demand for the highest quality is zero even if q_0 is sold at marginal cost. In this case, however, the highest quality firm is inactive and we can safely drop it from the set of firms considered. Doing so successively for all inactive top firms, the ratio $q_0 v_{\max}/c_0$ increases up to the point where $A_\delta + \alpha_\delta - 1$ is positive, which then defines positive markups throughout.

The equilibrium prices (8) consist of two additive parts. First, the part α_δ describes a constant markup over marginal production costs. Second, there is the auxiliary term A_δ that stems from the distorted price elasticity of the top quality firm. Intuitively, all firms have the same first order condition (6), but the top quality firm, which has just one direct competitor and an inelastic demand margin at the top end. Therefore, the top firm charges a distorted markup, represented by the auxiliary term A_δ. This distorted price of the top firm, in turn, implies that the second best firm, having a direct competitor with non-standard pricing behavior, prices its product in a non-standard way as well, yet slightly less than the top quality firm - its the auxiliary term is discounted by λ_δ^{-1} and equals $A_\delta \lambda_\delta^{-1}$. This logic applies to the third and the fourth best firm as well, finally explaining the perturbation term $A_\delta \lambda_\delta^n$ that is added to the constant markups α_δ and which, moreover, vanishes for firms very distant to the quality frontier. Figure 1 illustrates the two components of prices by plotting them as a function of quality q for the case $A_\delta > 0$.

For further intuition of the pricing formula (8), consider a situation where $A_\delta > 0$ holds, which implies that the maximal valuation $v_{\max}$ is large. In that case, the expression for the equilibrium prices (8) shows that the markup is higher for high quality firms. This implication is quite intuitive when interpreted in light of market shares and demand elasticities. In particular, recall that a price increase of a given firm induces its consumers at the upper and lower end of its market share to purchase qualities of competing firms (compare (5)). Obviously, the smaller the firm's market share, the severer is the drop of demand in percentage terms and therefore the demand elasticity. This effect is particularly obvious when considering the limit case of a vanishing market share, in which case any discrete price increase entirely eradicates the firm's demand. In sum, a higher market share comes along with a lower demand elasticity and thus with higher markups. Thus, for large $v_{\max}$ the top quality firm supplies an especially large market segment, enjoys a low demand elasticity, and thus charges markups above the industry average. This pricing behavior is precisely reflected by the positive value for A_δ.

With a good understanding of equilibrium pricing in the quality dimension, we turn next to the case of trade between two economies.

3 International Trade

We now consider a world of two countries, Home and Foreign (denoted by *), which are populated, respectively, by L and L^* individuals. The homogenous good $\mathcal{A}$ is costlessly traded, thus equalizing wages in both countries, as the according production technology is assumed to be equal worldwide. $\mathcal{Q}$-type goods can be traded subject to standard gross iceberg trade costs $\tau \geq 1$. The monopolistically competitive firms price discriminate between the export and domestic market.[16]

Consider a global industry producing the $\mathcal{Q}$-type good described above. As for the distribution of production sites of the different qualities, we will make the following assumptions. First, we assume that the relative spacing of qualities produced within each country (governed by the parameter δ from (4) in the previously considered case of autarky) is identical in both countries. Second, we assume that, if the top quality is produced in one country, the second best quality is produced in the other. Indexing the globally produced qualities by $n = 0, -1, -2, ...$ in descending order, these assumptions imply whenever every q_n is produced in Home, then q_{n-1} is produced in Foreign (and vice versa). Third, we assume that each quality q_n is positioned between the neighboring qualities q_{n-1} and q_{n+1} (produced abroad) according to the geometric average. This last assumption implies that

$$q_n = \gamma q_{n-1} \tag{14}$$

is satisfied. In particular, $\gamma = \sqrt{\delta}$ must hold, where δ is the relative spacing of qualities produced within an economy.

3.1 Optimal Pricing in the Open Economy.

We adopt the notation $c_n = \varphi q_n^\theta$ if n is located in Home and $c_n^* = \varphi^* q_n^\theta$ if n is located in Foreign. Adapting the firms' optimal pricing condition (7) to trade costs, consumer prices in Home are determined by the system

$$p_n = \begin{cases} \frac{1}{2}\left[c_0 + \left(1-\gamma^{-1}\right) q_0 v_{\max} + p_{-1}\right] & \text{if } n = 0 \text{ and firm 0 is in Home} \\ \frac{1}{2}\left[\tau c_0^* + \left(1-\gamma^{-1}\right) q_0 v_{\max} + p_{-1}\right] & \text{if } n = 0 \text{ and firm 0 is in Foreign} \\ \frac{1}{2}\left[c_n + \frac{1}{1+\gamma} p_{n+1} + \frac{\gamma}{\gamma+1} p_{n-1}\right] & \text{if } n < 0 \text{ and firm 0 is in Home} \\ \frac{1}{2}\left[\tau c_n^* + \frac{1}{1+\gamma} p_{n+1} + \frac{\gamma}{\gamma+1} p_{n-1}\right] & \text{if } n < 0 \text{ and firm 0 is in Foreign} \end{cases} \tag{15}$$

Just as in a closed economy we can derive the equilibrium prices in Home, given that all firms sell into Home's market.

[16] Nothing of the following analysis changes in presence of a larger number of $\mathcal{Q}$-type industries, which may differ in costs and maximum valuations $v_{\max}$. Potential trade imbalances between the aggregate of these industries are offset by costless trade in the homogeneous good $\mathcal{A}$, whose consumption levels are assumed to be high enough to do so.

Proposition 1 *Assume that (14) holds and firm locations alternate in n. Then, consumer prices in Home are*

$$p_n = \begin{cases} A\lambda^n + \alpha c_n & n \text{ in Home} \\ A\lambda^n + \alpha^* c_n^* & n \text{ in Foreign} \end{cases} \tag{16}$$

where

$$\alpha = \frac{2 + \tau \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} \frac{\varphi^*}{\varphi}}{4 - \left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2} \qquad \alpha^* = \frac{2\tau + \frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\frac{\varphi}{\varphi^*}}{4 - \left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2} \tag{17}$$

$$\lambda = \gamma + 1 + \sqrt{\gamma^2 + \gamma + 1} \tag{18}$$

and

$$A = \begin{cases} \frac{\lambda}{2\lambda - 1}\left(1 - 2\alpha + \alpha^* \gamma^{-\theta}\frac{\varphi^*}{\varphi} + \frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}\right) c_0 & n = 0 \text{ in Home} \\ \frac{\lambda}{2\lambda - 1}\left(\tau - 2\alpha^* + \alpha \gamma^{-\theta}\frac{\varphi}{\varphi^*} + \frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0^*}\right) c_0^* & n = 0 \text{ in Foreign} \end{cases} \tag{19}$$

Proof. Set $p_n = u_n + \alpha c_n$ if firm n is located in the domestic market and $p_n = u_n + \alpha^* c_n^*$ if not. Off the border condition, the system (15) for the consumer prices in Home is

$$\begin{aligned} 2\left[u_n + \alpha c_n\right] &= c_n + \frac{1}{\gamma+1}\left[u_{n+1} + \alpha^* c_{n+1}^*\right] + \frac{\gamma}{\gamma+1}\left[u_{n-1} + \alpha^* c_{n-1}^*\right] && n \text{ in Home} \\ 2\left[u_n + \alpha^* c_n^*\right] &= \tau c_n^* + \frac{1}{\gamma+1}\left[u_{n+1} + \alpha c_{n+1}\right] + \frac{\gamma}{\gamma+1}\left[u_{n-1} + \alpha c_{n-1}\right] && n \text{ in Foreign} \end{aligned}$$

The terms multiplied by c_n and c_n^* vanish iff

$$\begin{aligned} 2\alpha &= 1 + \left\{\frac{\gamma^\theta}{\gamma+1} + \frac{\gamma^{1-\theta}}{\gamma+1}\right\}\frac{\varphi^*}{\varphi}\alpha^* \\ 2\alpha^*\frac{\varphi^*}{\varphi} &= \tau\frac{\varphi^*}{\varphi} + \left\{\frac{\gamma^\theta}{\gamma+1} + \frac{\gamma^{1-\theta}}{\gamma+1}\right\}\alpha \end{aligned}$$

Solving for α and α^* leads to (17). The remaining problem is

$$2u_n = \frac{1}{\gamma+1}u_{n+1} + \frac{\gamma}{\gamma+1}u_{n-1} \qquad n < 0$$

with the general solution

$$u_n = A\lambda^n + B\mu^n$$

where $\lambda = \gamma + 1 + \sqrt{\gamma^2+\gamma+1}$ and $\mu = \gamma + 1 - \sqrt{\gamma^2+\gamma+1}$. The transversality condition $\lim_{n\to-\infty} p_n = 0$ and $\mu < 1$ imply $B = 0$. Equation (15) leads to

$$\begin{aligned} 2A + 2\alpha c_0 &= c_0 + \frac{\gamma-1}{\gamma}q_0 v_{\max} + A/\lambda + \alpha^*\gamma^{-\theta}\frac{\varphi^*}{\varphi}c_0 && \text{if } n = 0 \text{ in Home} \\ 2A + 2\alpha^* c_0^* &= \tau c_0^* + \frac{\gamma-1}{\gamma}q_0 v_{\max} + A/\lambda + \alpha\gamma^{-\theta}\frac{\varphi}{\varphi^*}c_0^* && \text{if } n = 0 \text{ in Foreign} \end{aligned}$$

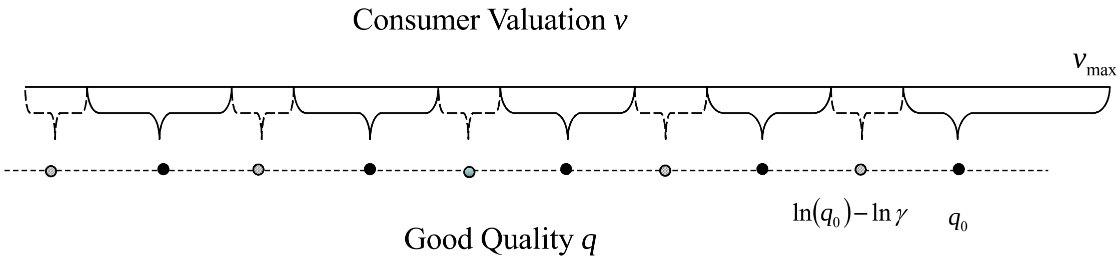

Figure 2: Equilibrium market segments for qualities produced by foreign firms (represented by lined dots) and domestic firms (solid dots).

Solving for A proves (19). ■

Just as in the case of autarky, consumer prices consist of two additive components: the constant relative markup α and the auxiliary term A, which is discounted by the weight $A\lambda^n$.

A close look at Home's domestic consumer prices (16) reveals that τ and φ^* enter the expression p_n only through the product $\tau\varphi^*$ (combine α^*, A and c_n^* from (3) to verify). This means that, for local prices in Home, it is irrelevant whether foreign firms are very productive (low φ^*) but need to incur high trade costs τ or whether, conversely, trade costs are low but production costs are high. Intuitively, the relevant expression is the sum of both costs – production plus trade costs.

Before proceeding, we need to verify the precondition under which (16) have been derived – i.e., that all firms sell into Home's market. If $A > 0$, this assumption holds when prices (16) exceed production plus trade costs for all firms: $\alpha \geq 1$ and $\alpha^* \geq \tau$. With expressions (17), these conditions can be written as[17]

$$\begin{aligned} \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\left[\frac{\varphi^*}{\varphi}\tau + \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\right] &\geq 2 \\ \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\left[\frac{\varphi}{\varphi^*} + \tau\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\right] &\geq 2\tau \end{aligned}$$

hold. Notice that in the limit $\gamma \to 1$ the two conditions become $\tau\varphi^*/\varphi \geq 1$ and $\varphi/\varphi^* \geq \tau$. These are jointly satisfied if and only if $\varphi = \tau\varphi^*$. Clearly, in this limit of a densely supplied market with zero markups, the transport costs must be exactly offset by a productivity advantage of the exporter. Since the ratio $(\gamma^\theta + \gamma^{1-\theta})/(\gamma + 1)$ is increasing in γ (compare (13)), the conditions are less demanding with larger γ: a wider spacing allows less productive firms – or firms with a

[17] In absence of trade costs and if $\varphi^* = \varphi$, these conditions are $2(\gamma + 1) > \gamma^\theta + \gamma^{1-\theta}$, which is equivalent to the condition on the positive α_δ under autarky, replacing $\delta = \gamma$.

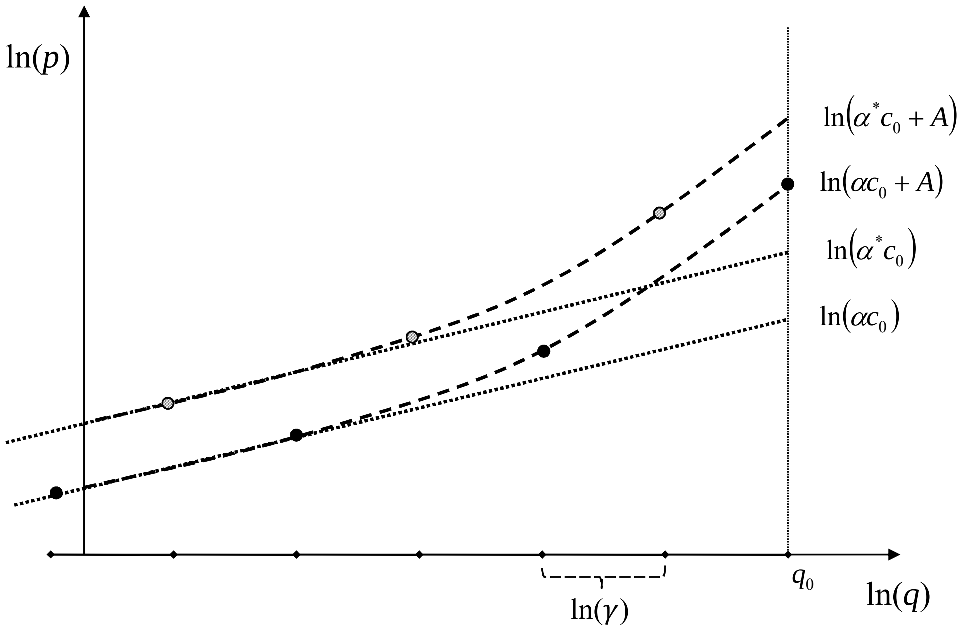

Figure 3: Equilibrium consumer prices of quality with costly trade between two economies. Lined dots represent qualities produced by foreign firms, solid dots represent those produced by domestic firms.

disadvantage due to transport costs – to sell into a market niche.[18]

As a first step in our analysis of the trade equilibrium, we will consider cases where technologies are equal across countries ($\varphi = \varphi^*$). Figure 2 depicts the equilibrium market segmentation in Home for this case, given that the current technological leader with quality q_0 resides in Home. In this figure, each solid dot represents a firm located in Home and each lined dot represents a firm located in Foreign. Domestic and foreign firms are placed at alternating locations on the quality spectrum. Each firm serves a range of consumers, yet because foreign firms face the transportation cost, they charge higher prices and thus serve a relatively smaller group of consumers.[19]

The corresponding prices are illustrated in Figure 3. Just like in the closed economy, prices consist of a constant markup over marginal costs ($\alpha^{(*)}$) plus a perturbation term $A^{(*)}$ that is discounted for low quality firms. In the case of the open economy, however, prices of imported goods are higher since they bear the trade costs in addition to production costs.

[18] Notice also that at $\varphi = \tau\varphi^*$ the consumer prices under trade (16) are identical to those in the closed economy (8).

[19] The very same effect occurs if $\tau = 1$ but $\varphi < \varphi^*$, as long as the term $\tau\varphi^*$ stays constant.

3.2 Trade Liberalization and Quality Pricing

In this section we investigate the impact of trade liberalization on domestic prices. That is, we will compare Home's domestic prices under autarky (when trade costs are infinitely high) with those that establish after a drop in trade costs to moderate levels that allow for positive trade volumes.

To gain a first basic intuition, we initially focus on low-quality firms ($n \to -\infty$), for which the term $A(\lambda/\gamma^\theta)^n$ plays only a negligible role. We can thus read the term α as the gross markup. In the special case of equal technologies and zero trade costs ($\tau = \varphi^*/\varphi = 1$), the location of firms turns out not to be relevant for pricing, which is identical to autarky pricing except for the fact that quality supply is much denser now: both, α and α^* in (17) coincide with α_δ from (9), but δ is now replaced by $\gamma = \sqrt{\delta} < \delta$. This means by (13) that $\alpha = \alpha^* < \alpha_\delta$: the constant component of the markups are higher in the case of autarky with less competition than under the intense competition in a world of frictionless trade.

Turning back to the more general case of productivity differences and positive trade costs, we also observe that, not surprisingly, α is increasing in τ: as trade frictions increase, competition for domestic firms is mitigated so that domestic markups decrease. At the same time, foreign markups over production costs α^*/τ tend to decrease as trade frictions rise: foreign firms are squeezed out of the domestic market and compensate their shrinking market shares by lowering markups and prices.

Interestingly, we can demonstrate that trade liberalizations can have substantial effects on domestic prices even if the volume of trade is very small and negligible. Consider the limit case where the low-quality foreign firms are *just* not selling into Home's market. The market segment of a foreign firm n approaches zero if $\underline{v}_n \to \overline{v}_n$ or, using the generic expressions (5) for the cutoff-valuations, if $(p_n - p_{n-1})/(1 - 1/\gamma) = (p_{n+1} - p_n)/(\gamma - 1)$. With the fourth line in (15), this condition becomes $p_n = \tau c_n^*$ or simply $\alpha_{\text{lim}}^* = \tau$. Using now (17), this condition is equivalent to

$$\frac{\tau\varphi^*}{\varphi} = \left[\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\right]\left[2 - \left(\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\right)^2\right]^{-1} \tag{20}$$

which, in turn, implies

$$\alpha_{\text{lim}} = \frac{1}{2 - \left(\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma + 1}\right)^2} \tag{21}$$

We can compare this expression with α_δ from (9). Using $\delta = \gamma^2 > \gamma$, it is quick to verify that $\alpha_{\text{lim}} < \alpha_\delta$ holds, where α_δ is the markup constant component under autarky from (9).

Economically, (21) implies that, even as foreign firms do not sell a single unit into the domestic market, their presence and the threat of their entry prompts domestic firms to charge lower markups. Notice that the increased competition at the top end of the quality distribution is not generating this effect. In the special case $A = 0$ (which is generated by the corresponding value of $v_{\max}$), none of the foreign firms sells into the domestic market, while the dampening effect of the presence of foreign firms on the markups on domestic firms is still present.[20]

Stating the same phenomenon from Home's perspective, local firms engage in limit pricing to exclude foreign competitors from the domestic market.

With this intuition in mind, we take a look at the general consumer prices (16). Here, the markups over production costs consist of both terms, α and the (discounted) term A. It is quick to verify that A may decrease in γ.[21] What matters, however, is the overall markup, consisting of α and A. For the top quality firm, it is

$$A/c_0 + \alpha = \frac{\lambda}{2\lambda - 1}\left(1 - \frac{\alpha}{\lambda} + \frac{\alpha^*}{\gamma^\theta}\frac{\varphi^*}{\varphi} + \frac{\gamma - 1}{\gamma}\frac{q_0 v_{\max}}{c_0}\right)$$

if firm $n = 0$ is located in Home. Simulations show that it is increasing in the spacing parameter γ. Consequently, markups of a firm n located in Home is

$$A(\lambda/\gamma^\theta)^n/c_0 + \alpha = A/c_0 + \alpha + \alpha\left[(\lambda/\gamma^\theta)^n - 1\right]$$

which is increasing in γ. In a similar way, the markup of foreign firms can be checked to be increasing in γ and all are increasing in the case when the top firm is located in Foreign.[22]

3.3 Quality Pricing-to-Market (PTM)

In this subsection, we analyze the dependence of consumer prices on market conditions and how this dependence differs across qualities. By market conditions we mean, in particular, the distribution of valuations governed by $v_{\max}$. Moreover, we will compare a firm's local price relative to its export price and how this ratio depends on the quality the firm produces.

When comparing the prices of two firms, we will do so holding technological conditions constant – i.e., we will compare the prices of two firms located in the same country. As discussed in

[20]This result differs from results in standard models of monopolistic competition with variable markups and international trade, such as for example Chen et al's (2009) dynamic analysis of the impact of trade integration on inflation in the framework of Melitz and Ottaviano (2008).

[21]Indeed, as γ grows, we know that $\alpha \to \infty$ so that $A \to -\infty$ must hold if markups are to stay bounded.

[22]It is immediate to check that $\frac{d}{d\gamma}\left[\frac{A}{c_0}\left(\frac{\lambda}{\gamma^\theta}\right)^n + \alpha\right] = \frac{d}{d\gamma}\left[\frac{A}{c_0} + \alpha\right] + \frac{d}{d\gamma}\left(\alpha\left[\left(\frac{\lambda}{\gamma^\theta}\right)^n - 1\right]\right)$. The first expression is increasing in γ as argued above, the second term is increasing as both, α and λ/γ^θ, are increasing in γ.)

connection with the expressions for prices (16), and recalling the assumption $\lambda > \gamma^\theta$ from (12), the term A is more important for the pricing of a firm, the higher the quality it produces. It turns out that this statement holds also marginally, i.e. as $v_{\max}$ increases, the prices increase of high quality firms are relatively steeper than those of low quality firms. Formally, we state the following

Proposition 2 *Consider firms n and m with $n > m$, located in the same country. Then, the relative price p_n/p_m from (16) is increasing in $v_{\max}$.*

Proof. Consider two firms located in Home indexed by n and m with $n > m$. Their relative price in the domestic market is

$$\frac{p_n}{p_m} = \frac{A\lambda^n + \alpha c_n}{A\lambda^m + \alpha c_m} = \frac{\frac{A}{\alpha c_n}\lambda^n + 1}{\frac{A}{\alpha c_m}\lambda^m + 1} = \frac{\frac{A}{\alpha c_0}(\lambda/\gamma^\theta)^n + 1}{\frac{A}{\alpha c_0}(\lambda/\gamma^\theta)^m + 1}$$

Prices are positive so that numerator and denominator are positive. As $(\lambda/\gamma^\theta)^m < (\lambda/\gamma^\theta)^n$ and since A is increasing in $v_{\max}$, this means that the fraction is increasing in $v_{\max}$.

Similarly, the price of the two firms located in Foreign charge in Home's market is

$$\frac{p_n}{p_m} = \frac{\frac{A}{\alpha^* c_0}(\lambda/\gamma^\theta)^n + 1}{\frac{A}{\alpha^* c_0}(\lambda/\gamma^\theta)^m + 1}$$

and by the same argument applied above, the fraction p_n/p_m is increasing in $v_{\max}$. The statement regarding consumer prices in Foreign follow by symmetry. ■

Next , we turn to a firm's export prices relative to those charged domestically. To that aim, we introduce p_n^* to denote the prices changed in the Foreign market, where, parallel to (16) firm n might be located in either country. Making use of this notation, our interest lies in the behavior of the ratio p_n^*/p_n.

To simplify the matter (and to reduce the number of cases that need to be distinguished and considered) we assume that technologies are equal across countries, i.e. $\varphi = \varphi^*$ holds. In this case, the prices charged by Home's firms in Foreign exhibit the same functional form (16) as the do the prices that Foreign firms charge in Home.[23]

Under these assumptions, we derive the following

[23] There is a difference in the auxiliary term A from (19), as the top firm $n = 0$ lies in the respective opposite market

Lemma 1 *Assume $\varphi = \varphi^*$ and that $v_{\max}$ is large in the sense that*

$$v_{\max} > \varphi q_0^{\theta-1} \frac{\gamma}{\gamma - 1} \left[-1 + 2\alpha - \alpha^* \gamma^{-\theta} \right] \quad \text{if} \quad n = 0 \quad \text{in Home}$$

or

$$v_{\max} > (\tau + 1)\, q_0^{\theta-1} \frac{\gamma}{\gamma - 1} \frac{\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} - \gamma^{-\theta}}{\left(2 - \frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1}\right)\left(\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} + 1\right)} \quad \text{if} \quad n = 0 \quad \text{in Foreign.} \tag{22}$$

Then, the markup charged in the export market over the markup charged in the domestic market is increasing in quality q, i.e.,

$$\frac{d}{dn} \frac{p_n^*}{p_n} > 0$$

holds.

Proof. See Appendix. ■

Lemma 1 derives an interesting implication of our pricing theory for how profitability of exports varies across firms producing goods of heterogeneous quality: if technology is scarce relative to consumer valuations (which implies $A > 0$), profit margins in the export market are more increasing in quality than they are in the domestic market – i.e. exporting is relatively more profitable for high quality firms than for low quality firms. We note that this result is akin to the "shipping the good apples out" conjecture, but it is not derived from the assumption that the ratio of transportation costs over the marginal cost of production is decreasing in quality (a feature which Hummels and Skiba (2004) derive from fixed per-unit shipping costs). Rather, in our analysis markups are increasing in quality if $A > 0$, so that even with iceberg transportation costs, the ratio of the profit margin of an exported good divided by the profit margin of the same good when sold domestically is increasing in quality. The opposite holds if $A < 0$.

We note that in the second case of Lemma 1 the technological leader is domiciled in Foreign, we require an additional restriction on technology to hold. The reason for this is that transportation costs then make the top-level technology q_0 more expensive at Home than abroad, which leads to the constant of the price schedule in Foreign (the equivalent of A from (19) in Foreign) being higher than the constant A of the pricing schedule in Home. As we document in the Appendix, in the case of $n = 0$ being located in Foreign, the markup charged in the export market over the markup charged in the domestic market is increasing in quality q for all Home firms under a condition on the scarcity of technology that is slightly more stringent than $A > 0$.

4 Quality and Exchange Rate Pass Through (ERPT)

We now turn to the analysis of how exchange rate changes, which we model as changes in relative productivity, are passed through to prices. Recall that marginal production costs are $c_n = \varphi q_n^\theta$ if n is located in Home and $c_n^* = \varphi^* q_n^\theta$ if n is located in Foreign. We now examine the rate of exchange rate pass through, defined as the elasticity of the price with respect to the marginal cost of production.

Looking at the equilibrium prices (16), we observe that quality pricing in export markets is quite similar to pricing in domestic markets in the sense that the markups consist of two parts (see Figure 3). First, there is the part described by (17), i.e. the markup component that is common among all domestic (foreign) firms. For prices of domestic firms, this term α is increasing in foreign firms' effective supply cost $\tau\varphi^*$. Intuitively, if foreign products become more expensive due to higher production or transport costs, competition in the domestic market becomes less tough, which allows domestic firms to charge higher markups. Conversely, the markup of foreign firms' effective supply costs (α^*/τ) decreases in the expression $\tau\varphi^*$: as the foreign firms' effective supply costs increase, their market share drops and the reduced market power prompts them to charge lower markups.

In addition, there is the perturbation term A that stems, just as in the closed economy, from the distorted price elasticity of the top quality firm. Consider the case when the top quality firm is located in foreign. In this case, one can expect that the negative impact of an increase in foreign production costs φ^* is mitigated by the top firm's privileged position: having only one direct competitor in the export market, the perceived competitive pressure for the top quality producer is less severe and its markup reacts less strongly than those of its fellow exporters. Conversely, if the top quality firm is located in the domestic market, an increase in foreign production costs φ^* affects only one (instead of two) of its direct competitors, so that the effect on markup might be positive, but only moderately so.

We can think of a shock to relative cost of production as a change in $\tau\varphi^*$. The rate of cost pass through is measured by the response in Home's import prices p_n (n in Foreign). In particular, it is quick to check with (17) that the term $\alpha^* c_n = \alpha^* \varphi^* q_n^\theta$ is increasing in foreign firms' effective supply costs $\tau\varphi^*$. At the same time, $\alpha^* c_n/\tau\varphi^*$ is decreasing in the effective supply costs $\tau\varphi^*$. Together, these observations show that the degree of exchange rate pass through to the common markup α^* is positive but incomplete.

But we are not only interested the rate of exchange rate pass-through of the common markup. Instead, we aim to analyze the full pass-through and specifically, how the pass-through rate varies with quality. Formally, this task is accomplished by determining the sign of the cross derivative

$$\frac{d}{dn}\frac{d}{d\varphi^*}\ln(p_n)$$

We do so in the following lemma.

Lemma 2 *(i) Assume that $v_{\max}$ is large (small) in the sense that $A > 0$ ($A < 0$). Then, relative markups over gross production costs p_n/c_n are increasing (decreasing) in quality q.*

(ii) Assume that $v_{\max}$ is large in the sense that

$$\begin{aligned} 2\alpha\varphi - \varphi - \alpha^*\varphi^*\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} &< \frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max} \quad \textit{if} \quad n = 0 \quad \textit{in Home} \\ \frac{\varphi}{2}\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} + \left[\alpha^*\frac{\varphi^*}{2}\frac{\gamma^\theta + \gamma^{1-\theta}}{\gamma+1} - \alpha\varphi\right]\gamma^{-\theta} &< \frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max} \quad \textit{if} \quad n = 0 \quad \textit{in Foreign} \end{aligned}$$

then, the degree of the exchange rate pass through is decreasing in quality q, i.e.

$$\frac{d}{dn}\frac{d}{d\varphi^*}\ln(p_n) < 0$$

Otherwise, the degree of the exchange rate pass through is increasing in quality q.

Proof. (i) Follows directly from (16) and $\lambda/\gamma^\theta > 1$.

(ii) see Appendix. ■

The results of the Lemma are quite intuitive, when reading them in light of market shares and demand elasticities. Thus, a price increase of a given firm induces its consumers at the upper and lower end of its market share to purchase qualities of competing firms (compare (5)). The smaller the firm's overall market share, the severer is the percentage drop of demand and thus of revenues. This effect is particularly obvious in the limit of vanishing market shares, when any discrete price increase entirely eradicates the firm's demand. By this effect, a higher market share comes along with a lower demand elasticity and thus with higher markups.[24]

Part (i) restates that, under the assumption that the maximal valuation $v_{\max}$ is large enough, demand for top quality is high. Thus, the top quality firms have a particularly large market share, and the according low demand elasticity allows them to charge markups above the industry average.

[24] The relation between the size of markups and the degree of pass through is a common theme in the literature on ERPT (see e.g. Gust et al. (2010)).

Part (ii), in turn, states that for high quality firms, the effect of an increase in supply costs is less strong than for lower quality firms. This observation reflects the relatively insensitive pricing behavior at the top end of the quality spectrum, which, in turn, is driven by the relatively price-insensitive demand that the top quality producer faces.

5 Testing the Role of Quality for PTM and ERPT in the European Car Industry

In this section, we document that good quality is an economically important determinant of pricing-to-market (PTM) and exchange rate pass through (ERPT) in the European car industry. Our evidence also suggests that markups (rather than local distribution costs) determine how quality is priced to market.

We examine a panel of cars sold in five markets from 1970 to 1999. Our data is from Goldberg and Verboven (2001 and 2005) and includes car characteristics such as the engine strength of a model, based on which we can construct several indices of car "quality." The data includes prices of the same car model sold in different markets, allowing us to analyze how the PTM and ERPT of the same good differs along the quality dimension.

Led by the above-discussed our theory, we focus on two main hypotheses: first, the increase of good prices in quality is steeper in richer markets (Proposition 2). To test this hypothesis, we exploit the variation in income across destination markets for a given car model. In doing so, we control for the unobserved heterogeneity in production costs by taking relative export prices as the dependent variable in most of our empirical specifications. Making use of relative prices – defined as the price of a car model in the import market compared to the price of the same model in its home market – we also confirm that relative prices are increasing in quality (Lemma 1, under the assumption that productivities are similar and export markets are rich). As the second main prediction of our theory we test whether the rate of exchange rate pass through is decreasing in quality (Lemma 2 (ii), under the assumption that export markets are rich). As a supplementary statement, we add that the latter effect should be stronger in richer markets, a prediction for which we find only some support.

Concerning the first prediction, we document that car quality is a determinant of the relative export price of a car model. A car's relative export price is generally increasing in the model's quality, i.e. compared to domestic prices, higher quality cars command higher markups when exported. Further, this effect is more pronounced for richer markets: high quality cars are especially expensive on rich markets. Concerning the second prediction, we document that exchange rate pass-through (ERPT) is larger for low than for high quality cars, and that this relation again depends on the income of the destination market.

The magnitude of the effects we uncover are economically significant. For example regarding price levels, we find that the interaction of car quality and market income can account for relative price differences in the order of magnitude of 10 percentage points, which is very significant compared to the margins in this industry. Also the estimates of ERPT rates convey that quality is a main determinant of firm's pricing decisions: the pass-through rate is below 10% for the highest decile of car quality, while it is around 20% the lowest decile of car quality.

Because we observe the price of the same car model sold on five markets, we can – building on Fitzgerald and Haller (2012) and Burstein and Jaimovic (2012) and on Simonovska (2011) and Cavallo et al. (2014) in the context of retail prices – focus on the evolution of the relative price at constant costs. We can thus control for the marginal cost of production and obtain estimates for markup differences.[25]

A caveat of our data is that we observe car prices at the retail level, and they thus include a distribution component. If distribution cost intensity is correlated with quality, the rate of pass-through will be correlated with quality, too, even in the presence of fixed markups (see Bacchetta and van Wincoop (2003), Burstein et al. (2003), Corsetti and Dedola (2005), Goldberg and Campa (2010), and especially Berman et al. (2012) in the context of heterogeneous firms). We employ two kinds of checks to verify if this possibility is responsible for our empirical findings. First, we follow Goldberg and Verboven (2001) and use the importer nation's producer price index as a gauge of the evolution of the local distribution costs. If the share of local distribution costs is related to the quality of a car, the response of the retail price of the car to the change in the local price index should be related to the car's quality. We document that this is not the case.

For the second check, we examine how distribution cost intensity affects pricing and pass through utilizing the nature of distribution in the car industry: cars are distributed to consumers via brand-specific dealer networks (see in particular the analysis of Brenkers and Verboven (2005)). These dealer networks and the associated distribution costs thus vary by brand rather than by car

[25] This feature of our data is especially important in the context of Amiti et al.'s (2012) finding that input use intensity differs across firms with different productivity, thus affecting firm specific pass through estimates. Given that it is well-established that good quality and firm productivity are positively correlated, it is likely that empirical estimates of pass-through regressions and how it differs with quality are distorted by input-use intensity. By focusing on the relative price of identical goods on different markets, we can abstract from this determinant of exchange rate pass through.

model within each brand, and thus distribution margins are constant within each brand (see also the direct quantification of dealer margins in Richartz (2009)). We thus estimate specifications that filter out all variation of prices and qualities across brands, markets, and time, and only utilize the within market & brand variation in quality (that is, we examine whether PTM of a Mercedes S class differs from that of an A class). While we find that distribution costs generally matter for PTM and pass-through, we find no evidence that distribution costs intensity is related to quality. Consequently, we argue that there is heterogeneity in PTM and pass-through along the quality dimension is due to varying markups.

We note that pricing in the car industry has been the subject of a sophisticated literature that identifies structural demand and supply parameters from observed car characteristics and aggregate sales (see Verboven (1996), Goldberg and Verboven (2001 and 2005), Benkers and Verboven (2005), and the literature deriving from Berry et al. (1995)). Particularly related to our analysis is also Feenstra et al.'s (1996) study on the determinants of exchange rate pass through in the car industry, and similar studies of pricing and pass-through on the European car industry of Gil-Pareja (2003), Garetto (2012), and Dvir and Strasser (2013). We view our regressions as complimentary to these exercises in that they point out the importance of a specific aspect - good quality - for PTM.[26]

5.1 Quality and Pricing-to-Market

Verboven (1996) and Goldberg and Verboven (2001 and 2005) document that large price differences exist for nearly identical car models across the five European markets. Based on the same data, we document that PTM differs systematically with quality: prices of identical car models differ along the dimension of quality. In the appendix of this paper, we follow Goldberg and Verboven (2005) and construct hedonistic indices of quality that relate the price of a car to its characteristics such as weight, horse power, and fuel efficiency. Since customers are willing to pay a higher price for more of an attribute such as "maximum speed" or lower "fuel consumption", these attributes reveal a car's quality.

Our first observation is that producers charge a higher markup when exporting high quality cars than they do when exporting low quality cars. Our second observation is that higher quality cars are relatively more expensive on richer markets.

[26] Garetto (2012) also examines the dataset of Goldberg and Verboven (2001 and 2005) to examine the relation between market share and pass-through, while Dvir and Strasser (2013) compile a new dataset of car prices and attributes that is more up to date and use it to re-investigate price convergence after the introduction of the Euro.

To establish these two facts, we first investigate how car characteristics affect the price of a domestically sold car compared to an imported car. We then evaluate how the relative price - i.e. the price of the same car sold in two different markets - varies with the car's quality. We view especially this latter investigation of relative price differences as informative, as the comparison of relative prices of the exact same good sold on five different markets keeps the marginal cost of production constant and can thus inform us about markup differences (see e.g. Fitzgerald and Haller (2012).

Quality and PTM. To assess the relation between quality and price levels, we estimate an econometric model of the type

$$p_{i,c,t} = \alpha + \beta q_i + \gamma q_i I_{c,t} + \delta x_t + \epsilon_{i,c,t}, \tag{23}$$

where $p_{i,t}$ is the logarithm of model i's price in country c at time t. This price is net of taxes and in special drawing rights (SDR). q_i is the model's hedonistic quality index and $I_{c,t}$ a measure of income per capita in the destination market; x_t is a set of included covariates (including fixed effects of destination countries), and $\epsilon_{i,c,t}$ the error.

In a first step, we only estimate the coefficient on quality, β, excluding the interaction term with income $I_{c,t}$. Columns (1) and (2) of Table 1 present random effects estimations (as fixed effects would soak up most variation in quality. The sample underlying the estimates of Column (1) consists of domestic prices, i.e. those charged in the country of production, the one of Column (2) consists of non-local prices of cars produced in the five countries. The quality measure is the engine power of the car expressed in Kilowatt (KW). More powerful cars are more expensive both when exported and when sold domestically, but the rate at which the price is increasing in engine strength is higher abroad (Column (2)) than at home (Column (1)). The estimations corresponding to Columns (1) and (2) both include importer and exporter fixed effects, so that the results are not driven by general cross-country differences.

Column (3) shows that this difference in how engine strength is priced at home and abroad is statistically significant. Here, the dependent variable is the relative price of a car model, defined as the price in the importing nation compared to price of the same model charged in the exporting country and expressed in the same currency (SDR):

$$p^{rel}_{i,c,t} = \ln \left[\frac{SDR \text{ Price in Importing Nation}_{i,t}}{SDR \text{ Price in Exporting Nation}_{i,t}} \right] \tag{24}$$

The relative price thus measures the price of the same car and expressed in the same currency in country c, normalized by the price in the export markets.

Column (3) presents a random effects estimation, in which the dependent variable is the model's relative price $p^{rel}_{i,c,t}$. Since we want to abstract from the fact that some markets are generally more expensive than others and that there might be comparative advantage across the five countries, we include both exporter and importer dummies in the estimation. The estimations show that the relative export price is increasing in the model's engine strength at a rate of 0.002. This is economically very sizeable: a one standard deviation (24 KW) higher engine power is associated with a 4.9% higher relative price abroad. Unless transportation and local distribution costs as a share of total costs are increasing in a car's engine strength, this implies that exporters charge a sizeable extra markup when exporting more powerful cars.

Columns (4) and (6) document that this extra markup for luxury exports also obtains when moving beyond using KW as the measures for car "quality". In column (4), the car's "class" is used as a measure of quality. The coefficient is estimated significantly positive at 0.011. This variable "class" takes values from 1 (subcompact cars) to 5 (luxury cars) so that the estimated coefficient implies the following: compared to subcompact cars, luxury cars are $(5-1)*0.011$ or 4.4% more expensive abroad than at home. In Columns (5) and (6), we include two measures of quality (Quality 1 and Quality 2, respectively, both defined in the Appendix A2) which corresponding to the car-model sold in the country of production. Again, we find statistically significant and economically large effects of quality on the relative price abroad.

We note that when we compare the relative price abroad, we cannot guarantee to always compare the exact same car model as manufacturers sell slightly different model configurations in the different markets. However, we stress that our results cannot be driven by a simple upgrading of exported cars. Such upgrading might indeed arise in the spirit of the argument of "shipping the good apples out" (see Hummels and Skiba (2004); Borstein and Feenstra (1987) analyze upgrading in the car industry).

We thus control for potential quality upgrading in the estimations reported in Columns (7) and (8), documenting that quality upgrading does not explain why the relative price abroad is increasing in quality. To do so, we not only, as before, include the quality of the car model sold in the country of production but, in addition, we control for the difference in the quality indices between the car model sold abroad and the one sold in the market of production. Both, when using quality index 1 (Column (7)) and quality index 2 (Column (8)), we find that differences in car qualities across the exporter and importer market are indeed important for understanding price differences. More importantly, however, we still find that higher quality cars are on average relatively more expensive abroad also when conditioning on the quality difference of the car at home and abroad.

Columns (9) and (10) document that global trends or shocks such as the oil crises cannot explain why high quality cars are relatively more expensive abroad. Indeed, a potential worry might be that common trends in trade integration, average car quality, and differences in price discrimination over time (as documented by Goldberg and Verboven (2001)) might interact in ways that generate the correlation between the relative price abroad and car quality. Moreover, our sample period includes the two oil crises, which severely affected the car industry. We thus include year effects to the estimation in columns (9) and (10), finding even stronger evidence that firms charge an export premium for high quality cars.

In all specifications of Table 1, we find that the relative export price is strongly increasing in the model's quality. The estimated coefficients are economically large. For example, compare the relative export price in the $10th$ percentile of car quality to the $90th$ percentile using the coefficient of 0.028 in Column (9). The respective percentiles are -1.26 and 1.37, so that the relative export price for a car model is $0.028 * (1.37 - (-1.26)))$, or around 7.4% higher for a car model in the $90th$ percentile of quality compared to one in the $10th$ percentile. Given that the profit share in this industry is generally in the single-digit region, this difference is quite sizeable.

Income, quality and PTM. We next examine whether the above-presented relations concerning the determinants of the relative price depend on the relative income of the destination market compared to the income of the exporter market. Examining how income affects PTM with the full specification of (23), we use the variable

$$I^{rel}_{c,o,t} = \ln \left[\frac{GDP/CAP \text{ in Importing Nation}_t}{GDP/CAP \text{ in Exporting Nation}_t} Exr^{-1}_{\text{Imp Currency/Exp Currency,t}} \right] \tag{25}$$

where c indicates the importing country and o the exporting country.

Table 2 reports how quality is priced across the five markets depending on relative income $I^{rel}_{i,t}$. It documents that prices are more increasing in quality in richer markets, and that this holds also in a strict relative sense: the ratio of the relative price of the same car sold in a rich and a poor nation is increasing in the interaction of relative income and car's quality. This relation is found holding fixed the basket of cars, evaluating relative prices, and when accounting for brand-specific distribution networks.

The first two columns in Table 2 jointly establish the basic result of the table: while prices are increasing in quality in all markets, the price schedule is steeper in quality in richer markets.

In Columns 1 and 2, the dependent variable is the logarithm of the price of a car model expressed in a common currency (SDR). The set of independent variables includes fixed effects for each market (to filter out average cross-country differences in prices) and year-fixed effects (to filter out trends and fluctuations). The sample in column 1 includes market years with below average income, while the sample in column 2 includes market years with above average income.

The dependent variable of interest is the quality index 1, which has a coefficient of 0.381 in the sample of richer markets, and a coefficient of 0.371 on poorer markets. Given that the dependent variable is measured in logarithms while quality is standardized, this means that an increase in quality by one standard deviation is associated with a 1.5 fold increase of the price in a high income market, while the same increase of quality is associated 1.4 fold price in a low income market. Compared to the relative price of a car with average quality, a car of quality 1 is around 10% cheaper in the poor market than in the rich market.

Motivated by this observation, we directly assess how relative income affects relative prices, and how this relation depends on quality. In Columns (3) to (7) of Table 2, the dependent variable is P_i^{rel}, the relative price of a car model as defined above in (24). Column 3 again (compare Table 1) documents that the relative price is generally increasing in quality, but does so also accounting for relative income. Relative income is, as defined in (25), equal to the logarithm of importer GDP per capita divided by exporter GDP per capita (both in real terms). Relative income of the destination market itself has no effect on the relative price.

Column 4 documents that the relative price is increasing in the interaction of car quality and destination market income. The specification includes the quality index of the car and the relative income of the destination market, and it includes these two variables interacted with each other. The estimated coefficient of the latter interaction term 0.051, which, together with the coefficient on quality itself of 0.014 implies the following: if the car is exported to a country with relative income of 0 (income per capita is the same in importer and exporter), the relative price increases with quality at a rate of 1.4% per standard deviation. If relative income is +0.25 (the destination market is 25% richer), this slope is nearly doubled ($1.4\% + 0.25 * 5.1\% \approx 2.7\%$), while if relative income is -0.25, the slope is roughly 0.

The evidence presented in Column 4 implies that the way how a good is priced-to-market depends on the interaction of the good's quality and the destination market's income. In terms of economic magnitude, these effects are quite pronounced. Consider, for example, two cars exported from a high income market ($95th$ percentile of relative income at 0.42) to a low income market

($5th$ percentile of relative income at -0.46). One of these cars is of low quality ($5th$ percentile of car quality at -1.56), the other is of high quality ($95th$ percentile of car quality at $+1.7$). The relative export price of the low quality car is equal to $+6.2\%$, i.e. the low quality car is 6.2% more expensive in the poor market. In contrast, the relative export price of the high quality car is equal to -3.8%, i.e. the high quality car is 3.8% more expensive in the high income market. In total, in this example, the interaction of car quality and market income can thus account for relative price differences in the order of magnitude of 10%, which is significant compared to the margins in this industry.[27]

Column 5 adds country-and-year fixed effects to the estimation and documents that the above relations are not driven by large country-specific fluctuations that jointly affect prices, qualities, and income. We note that because the specification of Column 4 relates relative prices to relative income and include year-fixed effects, it is unlikely that these relations are driven by country-specific trends that affect prices, qualities, and income. However, they could be driven by temporary country-specific fluctuations, and we thus include separate sets of year effects for each of the five markets.

The role of distribution costs for QPTM. One may possibly worry that findings are due to the fact that local distribution costs, measured as a share of total costs, is increasing in car quality. Indeed, for retail prices such as those we analyze here, it has been shown that local distribution costs are a substantial share of total costs in this industry, by some estimates up to 40% of total costs (see Verboven (1996)), although this number also includes fixed overhead cost such as marketing).

Before addressing the role of distribution costs directly in our estimations we note that the use of additional information from external sources points toward distribution costs being equally high as a share of costs for high and low quality cars. For example, in Germany, the Volkswagen company has a rule to pay a margin of 15% to dealers on all its models and brands (VW, Audi, Seat, and Skoda) whereas Opel, the German subsidiary brand of General Motors, gives its dealers margins ranging from 13.85% to 15.85%, again mostly irrespective of the type of the car sold (variability in dealer margins is rather related to the product life cycle). A study of dealer margins by Richartz (2009) that uses car data from Jato Dynamics documents that margins are roughly constant across cars of different classes.[28] Richartz (2009) also finds that the margins of

[27] The figures of 6.2% and -3.8%, respectively, are is the result of (0.014*-1.56)-(0.016*-0.88)+0.051*(1.56*0.88) and (0.014*1.7)-(0.016*-0.88)-0.051*(1.7*0.88).

[28] These figure were obtained from (accessed on 26.01.2012):

car dealers do not vary much across brands: in Europe, they are on average 15.9% for German producers, 16.9% for brands originating from other European countries (and US brands, but their share is minim), and 17.6% for Asian car producers.

For the US, the car website edmunds.com provides data allowing to directly direct test whether high quality cars are characterized by higher distribution cost. The site lists, for all model sold on US, the invoice price, i.e. the price that car dealers themselves pay and it also lists the Manufacturer's suggested retail price (MSRP). For example, the baseline BMW 3 series model carries an invoice price of USD $31,830$ and a MSRP of USD $34,600$, leaving the dealer with a margin of 8.7%. A comparison of the 30 imported car models with the highest US sales reveals that the car dealer margin is neither dependent on the invoice price or the class of a car.[29]

We next directly investigate the importance of local distribution costs in our regressions in Table 2, columns 6 and 7. Column 6 first documents that the above-documented relationship between PTM and car quality is found also when only utilizing variation in car quality within firms. The idea behind this regression is the following: cars are distributed to consumers via brand-specific dealer networks (see Brenkers and Verboven (2006)). These and the associated distribution costs thus vary by brand rather than by car model within each brand, but not by car within each brand. Column 6 thus estimate specifications that filter out all variation of prices and qualities across brands, markets, and time, and only utilize the within market & brand variation in quality. Again, the interaction of car quality and relative destination market income is increasing in car quality also when using this very subtle variation of the data.

Last, Column 7 documents that there is no relation between an index of the cost of local distribution, relative prices, and quality. We follow Goldberg and Verboven (2001) and use the importer nation's producer price index as a gauge of the evolution of the local distribution costs. The latter index by definition measures only the prices of domestic goods and services net of any imported consumption goods, and is thus a good measure of the cost index of the local distribution. If the share of local distribution costs is related to the quality of a car, we should observe a relation in the relative price of the car and the relative cost of distribution. We thus add the regressor $Q_{i,c} * \ln\left(P^{PPI}_{\mathrm{Im}porter}/P^{PPI}_{Exporter}\right)$ to the specification, and we also add the relative price level $\ln\left(P^{PPI}_{\mathrm{Im}porter}/P^{PPI}_{Exporter}\right)$ on its own to the regression. Doing so reveals that while this relative

www.kfz-betrieb.vogel.de/neuwagen/handel/articles/180387/
www.stern.de/wirtschaft/geld/autokauf-was-der-haendler-verdient-547617.html
automobilwoche.de/article/20110818/REPOSITORY/110819925/1279/neue-opel-ci-wird-teuer

[29] Edmunds.com was accessed on 26.01.2012.

price level matters for relative prices of traded cars (i.e. local distribution costs generally matter for pricing), there is no relation between quality and distribution cost intensity: the interaction of quality and the relative price index is insignificant.

We thus conclude that distribution costs cannot rationalize the documented relation between quality and PTM, thus leaving variable markups as explanatory factor.

5.2 Quality and ERPT

We next examine the implications of our theory regarding exchange rate pass through. We document that pass-through rates of exchange rate changes are higher for low quality cars than for high quality cars. We start by examining nominal prices following exchange rate movements and then examine the evolution of relative prices.[30]

Quality and nominal ERPT. Table 3 documents that high quality cars are characterized by a lower degree of exchange rate pass through. In all specifications of this table, the dependent variable is the change in the natural logarithm of the car price in the respective market.[31] In Columns 1 to 6, we include fixed effects for all model and market combinations. The exchange rate is always the bilateral year end value from Goldberg and Verboven (2001 and 2005) and we estimate one-year pass through regressions of the type

$$\Delta p_{i,c,t} = \alpha_i + \beta \Delta e_{c,o,t} + \gamma_j q_i \Delta e_{c,o,t} + \delta \Delta x_t + \epsilon_{i,c,t}, \tag{26}$$

where $\Delta p_{i,t}$ is the annual percentage change of model i's pre-tax price in country c in local currency; α_i the model-market fixed effect; $\Delta e_{c,o,t}$ the annual percentage change in the bilateral exchange rate between destination country c and origin country o; q_i the car's hedonistic quality index; Δx_t the set of included covariates, and $\epsilon_{i,c,t}$ the error.

Columns (1) to (3) of Table 3 compare our approach to a standard ERPT regression that does not take into account the role of quality. In Column 1 of Table 3, we include only the exchange rate change and consumer inflation to the regression. The (contemporaneous) pass-through rate

[30] Exchange rate movements are endogenous to productivity, wages, and many other macroeconomic variables. An advantage of focusing on the differential pass-through rate of different car groups is that while the exchange rate may be endogenous, the differential pass-through should not be biased if the endogeneity is equally strong for low and high quality cars, which we believe is a reasonable assumption.

[31] In Table 3, we only use those cars that are produced in the five markets under consideration. This is done in order to ensure that we can compare our results of nominal and relative price pass-through: when we estimate relative price pass through below, we need a price in the home market which we do not have for cars that are produced outside of Belgium, France, Italy, Germany and the UK. Unless otherwise noted, all specifications are weighted by the number of a model's sales, include fixed effects, and heteroscedasticity robust standard errors are reported in brackets below the coefficient point estimates.

is estimated at 13.1%. We add car quality (Quality Index 1) to this specification in Column 2. Although quality itself is a significant determinant of price changes, it does not affect the pass-through rate by much, which is estimated at 14%.[32]

Accounting for a car's quality has a large effect on pass-through rates. In Column 3 of Table 3, we allow pass through rates to be quality-dependent and add the interaction of Quality Index 1 and the exchange rate change. While the average pass-through rate is not much affected (it does not exactly unchanged since we have standardized quality for the sample of all cars but use only cars from five markets in this specification), the interaction is negative, significant, and economically large. A one standard deviation difference in quality is associated with a 6.3 percentage point different pass-through rate. For example, compare the $10th$ percentile of car quality to the $90th$ percentile. The respective percentiles are -1.26 and 1.37, so that the pass through rate of these two car qualities is 21.8% versus 5.3%, i.e. four times as large.

We next document the robustness of this result. Inflation, average car quality, and car prices might all be subject to common trends. We thus include a trend to the equation in Column (4). While the year trend is significant, this does not affect any other coefficient in our model (in fact the interaction coefficient is larger and significant at higher levels compared to the previous estimation). The trend itself has a negative coefficient, which might reflect the productivity advances in the car industry. In Column (5), we take into account that car prices are auto-correlated and add the lagged price change to the estimation. Indeed, prices are mean-reverting, but accounting for the mean reversion results in a larger coefficient for the interaction of quality and exchange rate changes.[33] The estimations in Column (6) repeats the baseline estimation of column (3) but does not weight observations by sales.

Goldberg and Verboven (2001 and 2005) use two different definitions of a car model. In our main specification, we use their narrow model definition "co." Their second model definition, "zcode" is somewhat broader than the main definition. For example, Daimler Benz discontinued the Mercedes 300 in 1992/3 and introduced the similar Mercedes E Class shortly thereafter. Our main definition classifies these two cars as two different models, but zcode counts them as one.

[32] Because we include fixed effects for each model sold on each market, the coefficient of quality has to be interpreted with care: if the quality of a model does not change during its life cycle, the fixed effects absorb all the variation associated with quality differences between cars. However, car manufacturers often upgrade the engine and other features of a model during its life cycle, and therefore the quality of a model can change slightly. Thus, the coefficient of "Quality Index 1" has the interpretation of how much a change in the quality of a car affects its price during its life cycle.

[33] To grant consistent estimation of model (26) that includes the lagged dependent variable as a covariate, we use the dynamic panel estimator developed by Arellano and Bond (1991) instead of a fixed effects panel regression.

Because car companies offer both the new and the old model of a car in the same year and on the same market, zcode does not uniquely define observations. We thus include market dummies and model dummies (by zcode) as fixed effect in Column (8). For better comparability, we also present the same specification (fixed effects by markets and models, but not all combinations) for our main model definition "co" in Column (7). Again, the interaction of exchange rate changes and car quality is negative, significant, and the coefficient is large.

Distribution costs, quality, and nominal ERPT. Columns (9) and (10) document that it is unlikely that local distribution costs explain the heterogeneous pass through response along the quality dimension (although distribution costs themselves are important for pass-through). For this, we first follow Goldberg and Verboven (2001) and use the importer nation's producer price index as a gauge of the evolution of the local distribution costs. We first add producer price instead of consumer price inflation in Column (9) showing that ppi inflation does substantially affect the price of all car models, thus pointing to the importance of local distribution costs.

If the share of local distribution costs is increasing in the quality of a car, the response of the local price to domestic PPI changes should be increasing in the quality, i.e. one needs to include not only the change in the local PPI change, but also its interaction with the quality index. Column (10) then documents that while ppi inflation does substantially affect the price of all car models, this response does not differ across cars of different quality (the interaction coefficient is estimated insignificantly). Moreover, the rate of ERPT is highly quality dependent also conditional on the inclusion of the PPI inflation and its interaction with car quality.

Column (11) of Table 3, we investigate whether the relation between quality and pass-through itself depends on the income of the destination market compared to that of the car's origin. This specification is motivated by out theory, in particular Lemma 2 (i). For this, we generate a dummy that is equal to one if income of the destination market exceeds that of the origin market and interact it with quality and the change in the exchange rate. Doing so reveals that the relation between quality and pass through is indeed much weaker in high income markets: the double interaction coefficient is estimated at -0.112, while the coefficient of the interaction of quality with the exchange rate itself is estimated at only -0.034. However, the coefficient of the double interaction is only significant at the 10% level. Thus, while the impact of income on the relation between quality and pass through seems to be economically very large, this cannot be said with high statistical significance. We note that Chen and Juvenal (2013) provide further evidence on the importance of the interaction of income and quality as a determinant of ERPT.

Quality and Relative ERPT. We next evaluate the response of the relative price of the same car in the importer market and the exporter market to exchange rate movements. We test whether this "relative pass-through rate" is higher for low quality than for high quality cars.

We believe that this test of relative price adds useful information as these relative prices of identical car models control for the evolution of the marginal cost of producing the good. Again, we stress that our data is contaminated by distribution costs so that the exchange rate should have less than a one-to-one effect on the price we observe even if firms completely pass through cost fluctuations. Still, this strategy based on relative prices enhances our understanding: as long as the price of the same model carries some information about the evolution of the (non-traded component) of the marginal cost of producing the car, it should be included in the regression. For example, it could be the case that firms producing high quality cars buy more inputs at world market prices, so that the relative cost of production moves more with the exchange rate in the low quality segment.

Throughout Table 4, the dependent variable is the change in the natural logarithm of the relative export price of a car, as defined in (24), expressed in the same currency. Instead of testing how absolute nominal prices responds to changes in the exchange rate, we test how relative prices react to the exchange rate.

In Column 1 of Table 4, we include relative consumer price inflation, i.e. the change in the natural logarithm of the ratio of CPI(importing nation)/CPI(exporting nation), thus reflecting the fact that we analyze relative prices. The effect of the exchange rate on the relative price, the "relative pass through-rate" is estimated at 16.5%, somewhat higher than the nominal rate in Table 3. This difference between relative and nominal pass through nearly vanishes once we also control for quality in Column 2. Again, to reflect the fact that we consider not the absolute but the relative price, we include an index of the relative quality (Quality Index 1 in the Importer Country– Quality Index 1 in the Exporter Country) to the regressions.

In Column 3 of Table 4, we document our main finding that relative price pass-through is much lower in the high quality car segment. Low quality cars are characterized by a much higher degree of relative pass through. This finding is even more pronounced than for nominal pass through. A one standard deviation in quality is associated with a 9.1 percentage points lower rate of pass through. This shows that the relative pass-through-differential is larger for than the nominal pass-through-differential.

To establish the robustness of this result, we add a time trend (Columns (4) and (5)), and also the lagged change in the price (Column (5); this specification is using the dynamic panel estimator from Arellano and Bond (1991)). Column (6) presents the baseline specification without weights, while the alternative definition of car models is used in Columns (7) and (8). The estimation in Column (7) presents the results from a regression which data dummies for each model (instead of each model-market combination as in the remainder of the Table), and Column (8) presents the result of a regression that uses the alternative definition of a car mode in Goldberg and Verboven (2001) (the "zcode" panel identifier). In Column (9), instead of only controlling for relative quality and relative inflation, we add quality in the importing market and quality in the exporter market separately, and we also add the two measures of consumer prices separately.

The role of distribution costs for relative ERPT. Column (10) documents that it is unlikely that local distribution costs explain the heterogeneous pass through response along the quality dimension. Specifically, we follow Goldberg and Verboven (2001) and use the importer nation's producer price index as a gauge of the evolution of the local distribution costs. As noted above already, if the share of local distribution costs is increasing in the quality of a car, the response of the local price to domestic PPI changes should be increasing in the quality. Hence, we include not only the change in the local PPI change, but also its interaction with the quality index. Column (10) documents that while ppi inflation does substantially affect the price of all car models (as the main effect is estimated positively and significant), this response does not differ across cars of different quality (the estimated coefficient of the relevant interaction is insignificant). At the same time, the rate of ERPT is highly quality dependent also conditional on the inclusion of the PPI inflation and its interaction with car quality.

Column (11) of Table 4 again investigates whether the relation between quality and pass through itself depends on the income of the destination market compared to that of the car's origin. We generate a dummy that is equal to one if income of the destination market exceeds that of the origin market and interact this dummy with quality and the change in the exchange rate. The according estimations reveal that also when measured in relative prices, the relation between quality and pass through is indeed much stronger in high income markets: the double interaction coefficient is estimated at -0.097, while the coefficient of the interaction of quality with the exchange rate itself is estimated at only -0.071. However, the coefficient of the double interaction is insignificant. Thus, while the impact of income on the relation between quality and pass through seems to be economically very large (just as in Table 3) this statement cannot be made with high statistical significance.

Table 5 documents that pass through rates vary along the quality dimension also at horizons longer than a year. Following Rigobon and Gopinath (2008), we measure pass-through by estimating a stacked regression where we regress yearly import price changes on yearly lags of the respective measure of the exchange rate.

$$\Delta p_{i,t} = \alpha_i + \sum_{j=1}^{n} \beta_j \Delta e_{t-j+1} + \sum_{j=1}^{n} \gamma_j \left(q_i \Delta e_{t-j+1}\right) + \sum_{j=1}^{n} \delta_j \Delta x_{t-j+1} + \epsilon_{i,t} \tag{27}$$

We estimate (27) up to the 5$-$year horizon.

The ERPT rates differ between high and low quality exporters at all horizons. Table 5 reports the (i.e. $\sum_{j=1}^{n} \beta_j$ and $\sum_{j=1}^{n} \gamma_j$ for main and interaction coefficient respectively). Panel A does this for the case of using quality measure 1. Here, the average rate of exchange rate pass through (equal to the main effect since the quality measure is of mean 0) is increasing from 13.2% at the one year horizon to 53.4% after 5 years. Also the difference in the ERPT rate between high and low quality exporters seems to increase with the time horizon. The magnitude of the interaction coefficient increases from 11% at the one-year horizon to 14.7%, 15%, and 23% at the 2, 3, and 4 year horizon respectively. However, the at the five year horizon, the interaction coefficient is estimated at only -15.6%. When using quality measure 2 in panel B, the effect of quality on pass through is empirically smaller in magnitude, but still significant.

6 Conclusion

We examine firm's pricing-to-market decisions in vertically differentiated industries featuring a large number of firms that compete monopolistically in the quality space. To this end, we draw on the literature on quality competition in the field of industrial organization and propose a model of quality pricing to market in an industry populated by a large set of firms each producing a good of unique quality. Foreign and domestic firms compete in the quality space and sell goods of heterogeneous quality to consumers with non-homothetic preferences that differ in their income and thus their marginal willingness to pay for quality increments.

We examine how quality is priced-to-market in the equilibrium of this model. Our main focus is on analyzing how firms producing goods of heterogeneous quality compete for consumers with heterogeneous preference for quality, and how this differs across different markets depending on national income. We first show that the relative price of high quality goods compared to that of low quality goods is an increasing function of income in the destination market. Our framework thus predicts that low quality goods are relatively more expensive in poor markets, while high quality goods are relatively more expensive in rich markets. We also examine the relation between income, quality, and the degree of exchange rate pass through. On a general note, our theoretical results imply that not the quality of a good itself is what is crucial for firms' PTM decisions, but the interaction of quality with market-specific demand for quality.

We also test the predictions of our theory in a dataset of prices and product attributes in the European car industry, documenting that PTM and exchange rate pass-through are indeed highly quality-dependent. In these markets, export prices over domestic prices are increasing in car quality and exchange rate pass-through is larger for low than for high quality cars. These relations depend on the income of the destination market: higher quality goods are relatively more expensive in markets with higher income, while exchange rate pass-through is more decreasing in quality in rich markets.

These empirical results, along with the findings of other recent empirical studies that examine how good attributes affect PTM decisions (see Dvir and Strasser (2013), Chen and Juvenal (2013), and Antoniades and Zaniboni (2013)) document that both in terms of relative price levels and in terms of exchange rate pass-through, the interaction of product attributes and demand for such attributes is indeed an important determinant of optimal prices.

We believe that the framework we develop also has other applications in the field of international trade. While we focus our analysis on the novel predictions regarding firm's pricing decisions, our model also generates novel predictions when compared to models of international trade with non-homothetic preferences (see e.g., the results in Fajgelbaum et al. (2011) or in Foellmi et al (2010)). Specifically, our model's prediction that trade has strong pro-competitive effects even if the volume of trade is small is of interest in context of the recent discussion on the relation between welfare gains from trade and observed import shares (see e.g Akorlakis et al. (2012)). Finally, our work may also be of interest to other aspects of this literature, such as the international product cycle or the impact of trade on inequality.

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Table 1 - Relative Price Levels (Random Effects Estimations)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	KW and Price at home	abroad	KW and relative Price	Cla and rel. Price	Quality 1 and rel. Price	Q2 and rel. Price	adjusting for Quality differences		adding time dummies	
	Sample: All Models that are produced in & exported to BEL, FRA, ITA, GER and UK									
Dependent Variable:	***(1)-(2) Ln Price SDR***				***(3)-(12) Ln (Price SDR Importer / Price SDR Exporter)***					
Engine Strength (KW)	0.021	0.023	0.002							
	(0.000)**	(0.001)**	(0.000)**							
Class (1= Subcompact, 5 = Luxury)				0.015						
				(0.003)**						
Quality Index 1					0.034					
					(0.003)**					
Quality Index 2						0.035				
						(0.004)**				
Quality Home Market (measure 1)							0.023		0.028	
							(0.004)**		(0.003)**	
Quality Home Market (measure 2)								0.025		0.029
								(0.004)**		(0.003)**
Quality Differential Home and Abroad (measure 1)							0.216		0.219	
							(0.018)**		(0.018)**	
Quality Differential Home and Abroad (measure 2)								0.266		0.269
								(0.022)**		(0.022)**
Year Dummies	n	n	n	n	n	n	n	n	y	y
Location Dummies	y	y	y	y	y	y	y	y	y	y
Market Dummies	y	y	y	y	y	y	y	y	y	y
Observations	2097	5926	5926	5926	5926	5926	5926	5926	5926	5926
Number of groups	255	809	809	809	809	809	809	809	809	809

Notes for Table 1: all specifications are estimated using random effects (groups: Market-Co-Location (all combinations) where "Co" is the narrow car model definition of Goldberg and Verboven (2005)); In Columns (7) to (10), the difference in the quality index of a model is included to capture changes of the quality of a car during the lifecycle of a model; the interpretation of the quality index coefficient is the effect a change in a model's quality has on the price; robust standard errors reported in parentheses * significant at 5%; ** significant at 1%.

Table 2 - Relative Prices and Income (Random Effects and Absorption Estimations)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Quality in GDP<Med.	Quality in GDP<Med.	Quality and Income	Interaction w. Quality	YE-MA Effects	BRD-YE-MA Effects	PPI * Quality
Sample: All Models that are produced in & exported to BEL, FRA, ITA, GER and UK							
Dependent Variable:	***(1)-(2) Ln Price SDR***		***(3)-(7) Ln (Price SDR Importer / Price SDR Exporter)***				
Quality Index 1	0.381***	0.371***	0.014***	0.014***	0.014***	0.023***	0.017***
	[0.006]	[0.005]	[0.004]	[0.004]	[0.004]	[0.002]	[0.006]
Ln Relative Income (Importer/Exporter)			-0.021	-0.016	-0.054***	-0.223***	0.467***
			[0.015]	[0.015]	[0.016]	[0.081]	[0.031]
Quality 1 * Ln Relative Income				0.051***	0.024**	0.021***	0.074***
				[0.012]	[0.010]	[0.006]	[0.025]
Relative PPI Level							0.161***
							[0.060]
Quality 1 * Relative Price Level							0.001
							[0.036]
Dummies by Year-Brand-Market						y	
Dummies by Year-Market					y		
Year and Market Dummies	y	y	y	y			y
Observations	2,600	3,326	5,640	5,640	5,640	5,640	3,692
Number of groups	566	540	764	764	764	-	547
R2 - Overall	0.964	0.961	0.333	0.336	0.525	0.84	0.331
R2 - Between	0.97	0.968	0.416	0.407	0.54	-	0.294
R2 - Within	0.914	0.87	0.0308	0.044	0.401	-	0.282

Notes for Table 2: all specifications except (6) are estimated using random effects (groups: Market-Co-Location (all combinations) where "Co" is the narrow car model definition of P. Goldberg and Verboven (2005)); (1)-(4) and (7) include year dummies and market dummies, while (5) includes year-by-market dummies (all possible combinations). (6) presents the results of a regression with Brand-Market-Year combinations absorbed. The quality index is as constructed in main text, relative income is equal to the ratio of real income in importer and exporter nation; robust standard errors reported in parentheses * significant at 5%; ** significant at 1%.

Table 3 - Nominal Exchange Rate Pass Through (Fixed Effects or Dynamic Panel Regressions)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Baseline ERPT	Adding Quality	Quality-dep. ERPT	Trend	Mean Reversion	Unwgted Estimation	No Change of Loc	zcode as Group	PPI Inflation	Local Distrib.	Income, Quality and PT
Estimation:	FE Panel	FE Panel	FE Panel	FE Panel	Dyn. Panel	FE Panel	FE Panel	FE Panel	FE Panel	FE Panel	FE Panel
	Sample: All Models that are produced in & exported to BEL, FRA, ITA, GER and UK										
	Dependent Variable is the Change of Ln Car Price (Local Currency, net of Taxes)										
dExrate = % Change of Exrate	0.159 [0.032]**	0.17 [0.031]**	0.147 [0.028]**	0.135 [0.028]**	0.116 [0.028]**	0.139 [0.023]**	0.142 [0.029]**	0.136 [0.027]**	0.066 [0.027]*	0.069 [0.027]*	0.143 [0.027]***
dExrate* Quality Index 1			-0.076 [0.030]*	-0.076 [0.029]**	-0.062 [0.026]*	-0.063 [0.023]**	-0.059 [0.025]*	-0.055 [0.024]*	-0.064 [0.025]*	-0.061 [0.025]*	-0.034 [0.029]
Quality Index 1		0.046 [0.008]**	0.046 [0.008]**	0.095 [0.010]**	0.251 [0.030]**	0.075 [0.010]**	0.071 [0.011]**	0.041 [0.007]**	0.091 [0.012]**	0.092 [0.012]**	0.046 [0.008]***
Trend (year)				-0.003 [0.000]**	-0.008 [0.001]**				-0.006 [0.001]**	-0.006 [0.001]**	
Lag 1 of % Price Change					-0.186 [0.028]**						
CPI Inflation Importer	0.796 [0.038]**	0.959 [0.044]**	0.948 [0.043]**	0.806 [0.046]**	0.861 [0.069]**	0.941 [0.048]**	0.911 [0.047]**	0.924 [0.045]**			0.946 [0.043]***
PPI Inflation Importer									0.27 [0.051]**	0.245 [0.054]**	
PPI Inf * Quality Index 1										-0.056 [0.052]	
dExrate* Quality Index 1 * High Income Dummy											-0.112 [0.063]*
Market Dummies	na	na	na	na	na	na	y	y	na	na	na
Observations	5216	5216	5216	5216	3730	5216	5216	5216	4012	4012	5,216
Number of groups	736	736	736	736	578	736	212	150	596	596	736
R-squared (within)	0.15	0.16	0.16	0.18	na	0.12	0.18	0.19	0.09	0.09	0.17

Notes for Table 6: specifications (1) to (6) and (9) to (11) include fixed effects by Market-Co-Location (all combinations) where "Co" is the narrow car model definition of Goldberg and Verboven (2005)); (7) includes fixed effects for Markets and Co separately; (8) includes fixed effects by Markets and zCode, where "zCode" is the wide definition of a car model in P. Goldberg and Verboven (2005). In Columns (2) to (8), the respective quality index is included to capture changes of the quality of a car during the lifecycle of a model; the interpretation of the quality index coefficient is the effect a change in a model's quality has on the price; In (11), the "High Income Dummy" is equal to one if the importer is richer than the exporter; main effects of interactions in (11) are included in estimation, but coefficients are not reported in the table; all specifications except (6) are estimated using the quantity sold as weight, the estimation in (6) is unweighted; robust standard errors reported in parentheses * significant at 5%; ** significant at 1%.

Table 4 - Relative Exchange Rate Pass Through (Fixed Effects Regressions)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Baseline ERPT	Adding Quality	Quality-dep. ERPT	Trend	Mean Reversion	Unwgted Estimation	No Change of Loc	zcode as Group	Home and For Variables	Local Distrib.	Income, Quality and PT
Estimation:	FE Panel	FE Panel	FE Panel	FE Panel	Dyn. Panel	Dyn. Panel	FE Panel	FE Panel	FE Panel	FE Panel	FE Panel
Sample: all models that are produced in & exported to BEL, FRA, ITA, GER and UK											
Dependent Variable is the percentage change (dLn) of the ratio of importer over exporter price (local currencies)											
dExrate = % Change of Exrate	0.171	0.167	0.132	0.129	0.116	0.144	0.158	0.151	0.13	0.092	0.124
	[0.044]**	[0.042]**	[0.038]**	[0.037]**	[0.033]**	[0.028]**	[0.038]**	[0.038]**	[0.041]**	[0.036]*	[0.037]***
dExrate * Quality Index 1			-0.111	-0.111	-0.046	-0.091	-0.083	-0.087	-0.088	-0.126	-0.071
			[0.037]**	[0.037]**	[0.035]	[0.027]**	[0.034]*	[0.034]*	[0.037]*	[0.032]**	[0.038]*
Difference in Relative Quality 1		0.243	0.244	0.244	0.217	0.235	0.236	0.237		0.259	0.244
(Importer Q1-Exporter Q1)		[0.023]**	[0.023]**	[0.023]**	[0.023]**	[0.020]**	[0.023]**	[0.023]**		[0.023]**	[0.023]***
Trend (year)				0	0						
				[0.000]	[0.001]						
Lag 1 of Change in					-0.232						
Ln (Relative Price)					[0.018]**						
Change in Ln Relative CPI	0.803	0.788	0.757	0.732	0.895	0.757	0.761	0.802			0.72
(Importer Infl. - Exporter infl.)	[0.051]**	[0.047]**	[0.048]**	[0.054]**	[0.089]**	[0.044]**	[0.044]**	[0.042]**			[0.054]***
Quality 1 Exporter									0.177		
									[0.024]**		
Quality 1 Importer									-0.202		
									[0.032]**		
Change in Ln CPI Importer									0.697		
									[0.072]**		
Change in CPI Exporter									-0.808		
									[0.078]**		
PPI Inflation Importer										0.103	
										[0.051]*	
PPI Inf * Quality Index 1										-0.044	
										[0.055]	
dExrate* Quality Index 1 * High Income Dummy											-0.097
											[0.071]
Market Dummies	na	na	na	na	na	na	y	y	na	na	na
Observations	4976	4976	4976	4976	3499	4976	4976	4976	4976	3855	4,976
Number of groups	719	719	719	719	555	719	204	144	719	582	719
R-squared (within)	0.08	0.22	0.22	0.22		0.21	0.25	0.26	0.14	0.19	0.23

Notes for Table 4: in all specifications, the dependent variable is the change in the natural logarithm of the relative car price in common currency (Importer SDR Price divided by Exporter SDR Price); the independent variable "Change in Ln CPI" measures the change in the ln of the ratio of importer CPI to the exporter CPI; in Columns (2) to (8) and (10 to (11), the relative quality index is included to reflect changes of the relative quality of a car during the lifecycle of a model; the interpretation of the relative quality index coefficient is the effect a relative change in a model's quality (in the importer relative to the exporter) has on the relative price; Columns (1) to (6) and (9) to (11) include fixed effects by Market-Co-Location (all combinations); (7) includes fixed effects for Markets and Co; (8) includes fixed effects for Market and zCode; In (11), the "High Income Dummy" is equal to one if the importer is richer than the exporter; main effects of interactions in (11) are included in estimation, but coefficients are not reported in the table; all specifications except (6) are estimated using the quantity sold as weight, the estimation in (6) is unweighted; robust standard errors reported in parentheses * significant at 5%; ** significant at 1%.

Table 5 - The Time Profile of ERPT and Quality

No. of Included Lags	Sum of Coefficients on Exchange Rate	Sum of Coefficients on Exchange Rate * Quality Index 1
	Panel A - Using Quality Index 1	
0	0.132	-0.111
	[0.038]**	[0.037]**
0-1	0.248	-0.147
	[0.049]**	[0.045]**
0-2	0.447	-0.150
	[0.050]**	[0.054]*
0-3	0.483	-0.230
	[0.070]**	[0.061]**
0-4	0.534	-0.156
	[0.116]**	[0.078]*
	Panel B - Using Quality Index 2	
0	0.146	-0.074
	[0.039]**	[0.035]*
0-1	0.269	-0.099
	[0.050]**	[0.040]*
0-2	0.465	-0.121
	[0.049]**	[0.050]*
0-3	0.502	-0.220
	[0.070]**	[0.062]**
0-4	0.539	-0.166
	[0.112]**	[0.075]*

Notes for Table 5: All specifications present the results from estimation of a stacked regression relating import price changes on lags of the exchange rate changes as in Rigobon and Gopinath (2008). The sum of the coefficients over the respective lags is reported (first column for the main effect of the exchange rate change and second column for the interaction effect of quality and exchange rate change). Panel A presents results from specifications that include the interaction of Quality 1 with the exchange rate change, while Panel B presents results from specifications that include the interaction of Quality 2 with the exchange rate change; robust standard errors reported in brackets * significant at 5%; ** significant at 1%.

Appendix

A1 Proofs

Proof of (13). Compute

$$\begin{aligned}
\frac{d}{d\delta}\frac{\delta^{\theta}+\delta^{1-\theta}}{\delta+1} &= \frac{\theta\delta^{\theta-1}+(1-\theta)\delta^{-\theta}}{\delta+1}-\frac{\delta^{\theta}+\delta^{1-\theta}}{(\delta+1)^2}\\
&= \frac{\theta\delta^{\theta}+(1-\theta)\delta^{1-\theta}+\theta\delta^{\theta-1}+(1-\theta)\delta^{-\theta}-\delta^{\theta}-\delta^{1-\theta}}{(\delta+1)^2}\\
&= \frac{(\theta-1)(\delta^{\theta}-\delta^{-\theta})+\theta(\delta^{\theta-1}-\delta^{1-\theta})}{(\delta+1)^2}>0
\end{aligned}$$

■

Proof of Lemma 1. We begin with some general observations. By $\varphi=\varphi^*$ and setting $\xi=\left(\gamma^{\theta}+\gamma^{1-\theta}\right)/(\gamma+1)$ we have

$$\alpha=\frac{2+\tau\xi}{4-\xi^2}\qquad\text{and}\qquad\alpha^*=\frac{2\tau+\xi}{4-\xi^2}$$

and

$$A=\begin{cases}\dfrac{\lambda}{2\lambda-1}\left(1-2\alpha+\alpha^*\gamma^{-\theta}+\frac{\gamma-1}{\gamma}\dfrac{q_0 v_{\max}}{c_0}\right)c_0 & n=0\text{ in Home}\\[2ex] \dfrac{\lambda}{2\lambda-1}\left(\tau-2\alpha^*+\alpha\gamma^{-\theta}+\frac{\gamma-1}{\gamma}\dfrac{q_0 v_{\max}}{c_0}\right)c_0 & n=0\text{ in Foreign}\end{cases}$$

Formally, the statement of this lemma (markup charged in the export market over the markup charged in the domestic market is increasing in quality q for all Home firms) is that

$$\frac{p_n^*}{p_n}=\frac{A(\lambda/\gamma^{\theta})^n+\alpha^*-\tau}{A(\lambda/\gamma^{\theta})^n+\alpha c_n-1}$$

is increasing in n. Thus, recalling (12) and considering both cases of the top firm's location, it is sufficient to show

$$\frac{A|_{n=0\text{ is Home}}}{A|_{n=0\text{ is Foreign}}}>\frac{\alpha^*-\tau}{\alpha-1}\qquad\text{and}\qquad\frac{A|_{n=0\text{ is Foreign}}}{A|_{n=0\text{ is Home}}}>\frac{\alpha^*-\tau}{\alpha-1}\tag{28}$$

which correspond to the two cases in part (i) and (ii) of the proposition.

(i) It is quick to check that

$$\frac{1-2\alpha+\alpha^*\gamma^{-\theta}}{\tau-2\alpha^*+\alpha\gamma^{-\theta}}\qquad\text{and}\qquad 1>\frac{\alpha^*-\tau}{\alpha-1}$$

so that the first condition in (28) holds always thus proving part (i) of the Lemma.

(ii) Consider next the case where $n=0$ is based in Foreign (the second condition in (28)). Using

(19), it is

$$\frac{\tau - 2\alpha^* + \alpha\gamma^{-\theta} + \frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}}{1 - 2\alpha + \alpha^*\gamma^{-\theta} + \frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}} > \frac{\alpha^* - \tau}{\alpha - 1}$$

which can be reformulated as

$$\frac{\gamma - 1}{\gamma}\frac{q_0 v_{\max}}{c_0} > \frac{(\alpha^* - \tau)\left(1 - 2\alpha + \alpha^*\gamma^{-\theta}\right) - (\alpha - 1)(\tau - 2\alpha^* + \alpha\gamma^{-\theta})}{\alpha - 1 - (\alpha^* - \tau)}.$$

Simplifying by using

$$\alpha^2 - \alpha^{*2} = -\frac{\tau^2 - 1}{4 - \xi^2} \qquad \alpha\tau - \alpha^* = \frac{(\tau^2 - 1)\xi}{4 - \xi^2} \qquad \alpha - \tau\alpha^* = -\frac{2(\tau^2 - 1)}{4 - \xi^2}$$

the numerator on the right hand side is equal to

$$\begin{aligned} \frac{1}{\gamma^\theta}\left(\alpha - \alpha^2 - \gamma^\theta\alpha^* + (\alpha^*)^2 - \tau\alpha^* + \alpha\tau\gamma^\theta\right) &= \frac{1}{\gamma^\theta}\left(\alpha - \tau\alpha^* + \gamma^\theta\left(\alpha\tau - \alpha^*\right) + \frac{\tau^2 - 1}{(4 - \xi^2)}\right) \\ &= \frac{\tau^2 - 1}{\gamma^\theta(4 - \xi^2)}\left(\gamma^\theta\xi - 1\right) \end{aligned}$$

while the denominator is equal to

$$\alpha - 1 - (\alpha^* - \tau) = (\tau - 1)\frac{\xi + 2 - \xi^2}{4 - \xi^2} = (\tau - 1)\frac{(2 - \xi)(\xi + 1)}{4 - \xi^2}$$

Hence, the relevant condition for relative markups being increasing in quality is

$$\frac{q_0 v_{\max}}{c_0} > (\tau + 1)\frac{\gamma}{\gamma - 1}\frac{\xi - \gamma^{-\theta}}{(2 - \xi)(\xi + 1)}.$$

■

Proof of Lemma 2 (ii). For all n in Foreign, we rewrite prices (16) as

$$p_n = \left[\frac{A(\lambda/\gamma^\theta)^n}{\alpha^*\varphi^* q_0^\theta} + 1\right]\alpha^*\varphi^* q_n^\theta$$

Taking derivatives of this expression leads to

$$\begin{aligned} \frac{d}{dn}\frac{d}{d\varphi^*}\ln(p_n) &= \frac{d}{dn}\frac{d}{d\varphi^*}\ln\left[\frac{A(\lambda/\gamma^\theta)^n}{\alpha^*\varphi^* q_0^\theta} + 1\right] + \frac{d}{dn}\frac{d}{d\varphi^*}\ln\left[\alpha^*\varphi^*\right] + \frac{d}{dn}\frac{d}{d\varphi^*}\ln\left[q_n^\theta\right] \\ &= \frac{d}{dn}\frac{d}{d\varphi^*}\ln\left[\frac{A/q_0^\theta}{\alpha^*\varphi^*}(\lambda/\gamma^\theta)^n + 1\right] \end{aligned}$$

Now, rewrite this last expression as

$$\frac{d}{dn}\frac{d}{d\varphi^*}\ln\left[g(\varphi^*)h(n) + 1\right]$$

where $g(\varphi^*) = A/(\alpha^* q_0^\theta \varphi^*)$ and $h(n) = (\lambda/\gamma^\theta)^n$. Then, compute

$$\frac{d}{dn}\frac{d}{d\varphi^*}\ln\left[g(\varphi^*)h(n)+1\right] = \frac{g'h'}{[gh+1]^2}$$

Observing that $h' > 0$ (by $\lambda > \gamma^\theta$) this last derivative is positive (negative) if and only if $g' > 0$ ($g' < 0$).

Case I: $n = 0$ in Home. In this case, (16) - (19) and the definition of g leads to

$$g = \frac{\lambda}{2\lambda-1}\frac{1-2\alpha+\alpha^*\gamma^{-\theta}\frac{\varphi^*}{\varphi}+\frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}}{\alpha^*\varphi^*}\varphi$$

so that

$$\begin{aligned}
\frac{dg}{d\varphi^*} &= \frac{\lambda\varphi}{2\lambda-1}\frac{1-2\alpha+\frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}}{\alpha^*\varphi^*} \\
&= \frac{\lambda\varphi}{2\lambda-1}\left[\frac{-2}{\alpha^*\varphi^*}\frac{d\alpha}{d\varphi^*} - \frac{1-2\alpha+\frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}}{(\alpha^*\varphi^*)^2}\frac{d(\alpha^*\varphi^*)}{d\varphi^*}\right]
\end{aligned}$$

With the derivatives

$$\frac{d\alpha}{d\varphi^*} = \frac{\frac{\tau}{\varphi}\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}}{4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2} \quad \text{and} \quad \frac{d(\alpha^*\varphi^*)}{d\varphi^*} = \frac{2\tau}{4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2} \tag{29}$$

the condition $dg/(d\varphi^*) < 0$ is satisfied if and only if

$$2\alpha - 1 - \alpha^*\frac{\varphi^*}{\varphi}\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1} < \frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{c_0}$$

which holds by assumption.

Case II: $n = 0$ in Foreign. In this case, g becomes

$$g = \frac{\lambda}{2\lambda-1}\frac{\tau-2\alpha^*+\alpha\gamma^{-\theta}\frac{\varphi}{\varphi^*}+\frac{\gamma-1}{\gamma}\frac{q_0 v_{\max}}{\varphi^* q_0^\theta}}{\alpha^*}$$

so that

$$\begin{aligned}
\frac{dg}{d\varphi^*} &= \frac{\lambda}{2\lambda-1}\frac{d}{d\varphi^*}\frac{\tau\varphi^*+\alpha\gamma^{-\theta}\varphi+\frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max}}{\varphi^*\alpha^*} \\
&= \frac{\lambda}{2\lambda-1}\left[\frac{\tau+\frac{\tau\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}}{4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2}\gamma^{-\theta}}{\varphi^*\alpha^*} - \frac{\tau\varphi^*+\alpha\gamma^{-\theta}\varphi+\frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max}}{(\varphi^*\alpha^*)^2}\frac{d(\alpha^*\varphi^*)}{d\varphi^*}\right]
\end{aligned}$$

By (29), the condition $dg/(d\varphi^*) < 0$ is satisfied if and only if

$$\tau + \frac{\tau\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}}{4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2}\gamma^{-\theta} - \frac{\tau\varphi^* + \alpha\gamma^{-\theta}\varphi + \frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max}}{(\varphi^*\alpha^*)}\frac{2\tau}{4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2} < 0$$

or

$$\varphi^*\alpha^* + \frac{\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\varphi^*\alpha^*}{4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2}\gamma^{-\theta} < \left[\tau\varphi^* + \alpha\gamma^{-\theta}\varphi + \frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max}\right]\frac{2}{4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2}$$

or

$$\varphi^*\alpha^*\left[4-\left(\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right)^2\right] + \frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\varphi^*\alpha^*\gamma^{-\theta} < 2\left[\tau\varphi^* + \alpha\gamma^{-\theta}\varphi + \frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max}\right]$$

or

$$\left[\varphi\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1} + \varphi^*\alpha^*\gamma^{-\theta}\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1}\right] < \left[2\alpha\gamma^{-\theta}\varphi + 2\frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max}\right]$$

or

$$\frac{\varphi}{2}\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1} + \left[\alpha^*\frac{\varphi^*}{2}\frac{\gamma^\theta+\gamma^{1-\theta}}{\gamma+1} - \alpha\varphi\right]\gamma^{-\theta} < \frac{\gamma-1}{\gamma}q_0^{1-\theta}v_{\max}$$

which holds by assumption. ■

A2 – Data Description

The data on car prices, quantities, and quality attributes used in this study is from Goldberg and Verboven (2001 and 2005). Their data set also includes relevant macroeconomic information such as exchange rates and inflation rates.[34] It covers cars sold on five European Markets (Belgium, France, Germany, Italy, and the UK) in the period from 1970 to 1999. Although we only have prices for cars sold in these markets, the cars originate from 14 countries.

Defining "Quality" Before describing the data in more detail, we construct a measure of car quality. Following Goldberg and Verboven (2005), we construct hedonistic indices of quality that relate the price of a car to its characteristics such as weight, horse power, and fuel efficiency. Since customers are willing to pay a higher price for more of an attribute such as "maximum speed" or lower "fuel consumption", these attributes reveal a car's quality.

In Table 1, the dependent variable is the natural logarithm of the car price net of VAT and in Special Drawing Rights (SDR).[35] All car prices in our sample are for the basic configuration of each car model, i.e. the cheapest version actually offered on a market. We estimate random effects panels since including fixed effects by car model would account for nearly all of the quality variation in our sample.

Goldberg and Verboven (2001 and 2005) find significant evidence of price discrimination across the European markets and we thus include market fixed effects to the regression. We also include consumer price inflation to the specification. Last, we include a trend to account for the fact that technological progress might make car production cheaper in general.

In Table 1, and unless otherwise stated also in the rest of the paper, we take the baseline definition of a car model in Goldberg and Verboven (2001 and 2005). In the panel, a group is defined as one car model sold in one market so that we have 1554 groups and 379 car models.[36]

In Column (1) of Table A1, we regress the logarithm of a car's price on a Luxury Dummy that equals 1 if the car is either counted as "Intermediate Class" or "Luxury Class" in official car guides. The interpretation of the coefficient of the luxury dummy is the following. If two car models are sold on the same market and in the same year, yet one is a Luxury or Intermediate car

[34] The data is described in detail in Goldberg and Verboven (2005). It can be accessed on the webpages of either author.

[35] SDRs are a basket of major currencies with weights updated every 5 years.

[36] We note that in order to properly reflect changes in the exchange rate, we count a car model as a new observation when the location of production changes. This happens in less than 20 instances. Moreover, a change of the production location is mostly a Japanese firms re-locating production to Europe. In the sample of cars that are both produced and sold in our five markets, there are only 3 car models that are counted twice.

while the other one is not, the price differential is on average 0.698 log points (around 2−fold).

In Column 2 of Table A1, we relate car prices to "measurable" measures of quality. We include horsepower, fuel efficiency, cylinder volume, size, weight, and maximum speed. All measures have the expected sign except height, which has a negative coefficient, potentially because expensive sport cars tend to be flat. Conditional on the other car characteristics, a one KW stronger engine is associated with a 0.55% higher price. The overall fit of the model is very good, with an R^2 of 92.6%, but we can do even better by also including "soft" car attributes such as the car brand. In Column 3, we thus add brand dummies and class dummies to the estimation.

We next predict two indexes of car quality. We predict "Quality Index 1" from Column 2 of Table A1. Since conditional on the car characteristics, where and when a car is sold should not influence its quality, and since, moreover, consumer price inflation does not affect the quality of a car, we partial out these variables when predicting the quality index. We next predict "Quality Index 2" from the model in Column 3 of Table A1. For Quality Index 2, we again partial out the effect of when, where, and at what level of consumer prices a car was sold, but we include the brand and class dummies. After predicting, we standardize both indices of quality for better interpretability of the results.

Data description: which cars are traded? Having constructed the hedonistic quality indices, we describe our data in detail in Tables A2 and A3. Table A2 reports the summary statistics of our sample of cars. The structure of Table A2 is the following. We first summarize the whole sample in Panel A and then partition this sample into three subsample. Panel B only summarizes only domestic prices – i.e. the retail prices charged in one of the five countries (BEL, FRA, GER, ITA, and UK) of those cars that were produced locally. Panel C summarizes the retail prices charged in one the five countries of cars that were produced in one the five countries, but not locally. Finally, Panel D summarizes the retail prices changed in one of the five countries of cars produced in neither of the five countries.

For these four groups of cars, Table A2 reports the summary statistics for the quantity sold, prices, and quality. In addition to the usual statistics (un-weighted mean, un-weighted standard deviation, minimum, and maximum), we also report the weighted mean quality index. As smaller, less expensive car models tend to have much higher sales than luxury cars, the weighted average quality is negative on average. Table A2 documents that high quality cars are exported more often. To confirm this observation, compare the average quality in Panel B to the one in Panel C: the weighted average of Quality Index 1 of those cars exported and sold domestically is −0.348, while the same average in the group of cars produced in one of the five markets and exported to the other four markets is 0.04 higher than that. Also when evaluating the alternative quality index and/or the unweighted means, exported cars tend to be of higher quality than domestically sold cars.

We present some more information about the variability of our changes in Table A3. The upper part of Table A3 presents summary statistics for the annualized change in the natural logarithm of a model's price, changes in the exchange rates, and annual CPI inflation. We also display the annual change in the logarithm of the relative price. The relative price is the ratio of the price of a car in the importer market divided by the price of the same car in the market of production. In the main specifications that we present below, we focus on car models that are produced in Belgium, Italy, Germany, France, or the UK and sold on one of the other four markets. We thus present the summary statistics only for this group of observations.[37]

There are no outliers for the annual exchange rate fluctuation or for the annual inflation rates. However, some of the year-to-year price changes (and more so for relative price changes) are quite large. The lower part of Table A3 lists any observation where either the nominal or the real price changed by more than 0.5 log points (a 64% change) from year to year. Such a large price change does never occur for the same model. The underlying reason for these fluctuations is that the base model is sometimes discontinued in some markets, while other versions are still offered. Since Goldberg and Verboven (2001 and 2005) always use the price of the base model that is actually available on a market (and do not treat this as a new model) the price may jump from year to year. Nevertheless, we include these observations in the main regression because in such incidences drastic changes in the nominal price and in the observed car quality concur and are thus controlled for in our regressions.[38] All regressions presented below account for that change in quality, and hence the quality-adjusted price change is much smoother.

[37] When using the full sample, we drop all cars from former Yugoslavia that went through a hyperinflation episode during the early 90's.

[38] We thank Penny Goldberg and Frank Verboven for pointing out this feature of the data.

Table A1 - Quality Attributes and Prices: Random Effects Estimations

	(1)	(2)	(3)
	Luxury Dummy	*Quality Index 1*	*Quality Index 2*
	Dependent variable is Ln price in SDR, net of taxes		
Luxury Dummy (Cla= 4,5)	0.698		
	[0.017]**		
Horsepower (in kW)		0.0055	0.0047
		[0.0003]**	[0.0003]**
Fuel efficiency (L/100 km)		-0.0143	-0.0138
		[0.0016]**	[0.0016]**
Cylinder volume (in l)		0.18467	0.16784
		[0.0122]**	[0.0119]**
Weight (in t)		0.2145	0.10811
		[0.0282]**	[0.0282]**
Length (in m)		0.2316	0.1474
		[0.0149]**	[0.0169]**
Width (in m)		0.0464	-0.1031
		[0.0547]	[0.0539]
Height (in m)		-0.4514	-0.3620
		[0.0603]**	[0.00058639]**
Maximum speed (km/hour)		0.0013	0.0011
		[0.0003]**	[0.0003]**
Trend (year)	y	y	y
CPI Inflation	y	y	y
Market Dummies	y	y	y
Class Dummies			y
Brand Dummies			y
Observations	11510	11510	11510
Number of Groups	1554	1554	1554
R-Sq.within	82.8%	84.6%	84.8%
R-Sq. between	82.1%	94.4%	96.3%
R-Sq. total	81.9%	92.9%	94.5%

Notes: In all specifications of Table A1, the dependent variable is the natural logarithm of the price in Special Drawing Rights (SDR) and net of taxes. All models include a year trend, CPI inflation, and import market dummies. A group is identified by a model (co_loc) sold on one market. The specification uses "Li" as measure of fuel efficiency (average of "Li1", "Li2", "Li3"); robust standard errors in parenthesis; * significant at 5%; ** significant at 1%.

Table A2 - Data Description (Cars and Quality)

	(1)	(2)	(3)	(4)	(5)
Variable	***Mean***		***Std. Dev.***	***Min***	***Max***
	weighted	***unweighted***	***unweighted***		
Panel A: All models, all markets, and all years					
(11510 Model-Market-Years, 1554 Model -Years, and 379 Models)					
Price in SDR	6010	6627	4512	681	39665
Quality Index 1	-0.337	0	1	-2.247	3.927
Quality Index 2	-0.331	0	1	-1.949	3.855
Quantity (per Market and Year)	-	19868	37771	51	433694
Panel B: Models produced and sold domestically in market of production (BEL, FRA, GER, ITA, or UK)					
(2097 Model -Years and 255 Models)					
Price in SDR	5785	6214	4330	681	35398
Quality Index 1	-0.348	-0.055	1.005	-2.247	3.927
Quality Index 2	-0.288	-0.006	0.993	-1.949	3.855
Quantity (per Market and Year)	-	65505	65660	300	433694
Panel C: Models Produced in BEL, FRA, GER, ITA, or UK and Exported to other 4 markets					
(6161 Model-Market-Years, 833 Model - Years, and 241 Models)					
Price in SDR	6345	6518	4698	691	39665
Quality Index 1	-0.304	-0.009	1.022	-2.247	3.927
Quality Index 2	-0.277	0.047	1.013	-1.949	3.854
Quantity (per Market and Year)	-	10726	15196	51	175812
Panel D: Models Produced Outside of BEL, FRA, GER, ITA, or UK					
(3252 Model Market Years, 466 Model-Years, and 110 Models)					
Price in SDR	6354	7099	4223	963	34561
Avg. Quality Index 1	-0.36	0.052	0.950	-2.020	3.396
Avg. Quality Index 2	-0.48	-0.086	0.973	-1.913	2.956
Quantity (per Market and Year)	-	7759	13602	53	157612

Notes: In Table A2, there are in total 379 models, of which 14 are only exported and not sold in the home market. The quality indexes are predicted from the respective model in Table A1 partialling out the effect of inflation, year, and market. The quality indexes are also standardized. For the Relative Avg. Quality Index, each the average of car quality is weighted by the quantity sold, and this average is then demeaned by year (but not by market).

Table A3 - Summary Statistics of Yearly Fluctuations and List of Outliers

Sample consists of all car models that are produced in BEL, FRA, ITA, Ger, and UK and exported to the other 4 markets

	Observations	Mean	St Dev.	Min	Max
dExrate =ΔLn(Bilateral Exchange Rate)	5216	-0.0005858	0.0703469	-0.266955	0.266955
dPrice = ΔLn(Car Price in Local Currency)	5216	0.0700733	0.0869908	-0.8905315	0.8134804
dPrice_Relative= ΔLn(Price Import Market/ Price Home Market), Prices in local currencies	4976	-0.0041548	0.1012984	-0.9666461	0.7753934
dCPI = ΔLn(CPI Importer)	5216	0.0592325	0.0440829	-0.0024832	0.2170054
dCPI_Relative= ΔLn(CPI Import Market / CPI Home Market)	5216	0.0004058	0.0435519	-0.1593031	0.1593031

List of Observations with |dPrice|>0.5 or |dPrice_Relative|>0.5

Year	Importer (ma)	Exporter (loc)	Car Model	dPrice	dPrice_Relative	Change of Q1	Level of Q1
74	Italy	Germany	Opel Record	0.6032	0.4798	0.0000	0.3566
75	Italy	Germany	Opel Record	0.5163	0.4440	0.4816	0.8382
75	Belgium	Italy	Fiat 124	0.5991	0.1291	0.5722	0.0898
75	France	Italy	Fiat 124	0.5728	0.1028	0.5722	0.0898
75	UK	Italy	Fiat 124	0.6705	0.2005	0.5722	0.0898
76	UK	Germany	VW Beetle 1200	0.3793	0.5065	0.0000	-1.0821
77	UK	Italy	Fiat Argenta	0.5054	0.1929	0.4228	0.8267
79	Belgium	Germany	VW Beetle 1200	0.6118	na	0.3029	-0.7792
81	Germany	France	Peugeot 504	0.7080	0.6024	0.5107	0.8290
84	Italy	Germany	Audi 100/200	0.7056	0.6729	0.7017	1.3252
93	Belgium	Italy	Lancia Delta	0.8135	0.7754	1.5782	1.6892
94	Belgium	Italy	Lancia Delta	-0.8905	-0.9666	-1.6259	0.0632
95	Belgium	France	Renault 19	-0.1199	-0.6930	0.0000	-0.2130
95	Germany	France	Renault 19	0.0123	-0.5608	-0.2066	0.0171

Notes: The upper part of Table A3 presents summary statistics for changes of exchange rates, prices, and CPI inflation. The summary statistics are presented for all cars that are produced in BEL, FRA, ITA, GER, and the UK and that are sold on at least one of four possible export markets in our sample; when presenting the summary statistics for relative prices, the models that are not sold in the country of production and thus have no "Home Market Price" are dropped; The lower part of Table A3 lists outliers that had year-top-year price changes of more than 0.5 log points or relative price changes of more than 0.5 log points.